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Journal of the Marine Biological Association of India

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The Investigator

VOLUME I, No. 1

JUNE 1959

PUBLISHED BY
THE MARINE BIOLOGICAL ASSOCIATION OF INDIA
MARINE FISHERIES P.O., MANDAPAM CAMP
S. INDIA

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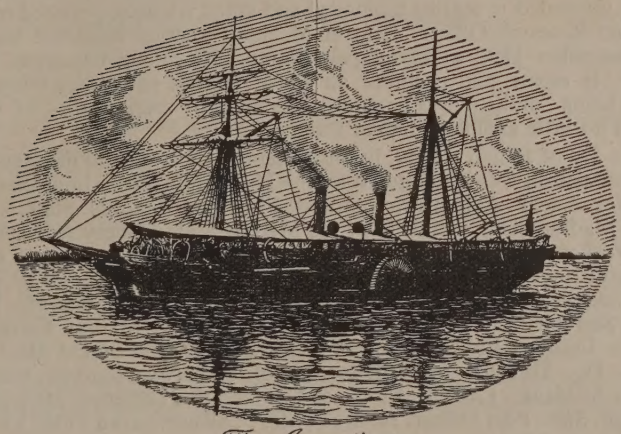

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The seas around India have been exploited for centuries, but a real impetus to marine research was provided only in the beginning of this century. Most of the early work was carried out by the Marine Survey of India, Madras Museum and the various marine biological stations established by the Madras Government. These investigations gave an incentive to the Indian biologists to further their knowledge of the marine fauna and flora of the Indian waters. Since then, marked strides have been made in fundamental researches in marine biology and cognate sciences, especially at the Universities of Madras, Kerala, Bombay, Andhra and Annamalai. And, with the advent of the Marine Fisheries Research Station of the Government of India, rapid progress has been seen in applied as well as fundamental studies on marine life in Indian waters. It was indeed a long-felt desire to bring together the various marine biologists in India and this is now achieved by the formation of the MARINE BIOLOGICAL ASSOCIATION OF INDIA—the first of its kind in the East. This organization was founded at a well-attended meeting of persons interested in marine biological and allied sciences, presided over by Dr. S. Jones, Chief Research Officer, Central Marine Fisheries Research Station, on the 30th of December 1958, at Mandapam Camp. The main objectives of the Association are to create and promote an active interest in studies related to marine flora and fauna, and to give possible assistance in such studies of the relatively unknown and little exploited Indian waters.

On the 3rd of January, 1959, in the presence of a large and distinguished gathering, the Association was inaugurated by the Honourable Mrs. Lourdhammal Simon, Minister for Local Administration and Fisheries, Madras State. All fisheries officers of Madras State, members of the Madras State Fishery Advisory Board and research workers of the Central Marine Fisheries Research Station were present. Among the distinguished guests who attended the function were : Dr. F. B. Salvadori, F.A.O., Underwater Expert; Mr. P. P. I. Vaidyanathan, I.C.S. ; and Mr. N. Murugesa Mudaliar, Secretary and Deputy Secretary respectively, Madras Government; Mr. C. P. Kelu Erady, I.A.S., Director of Fisheries, Madras State; Mr. D. D. Peter Devadoss, Dy. Director (now Director) of Fisheries, Madras State ; Mr. A. Palaniappa Mudaliar, I.A.S., Registrar of Co-operative Societies, Madras State ; Mr. C. Sankunni, State Port Officer, Madras ; Mr. P. Sivasankaran Pillai, I.A.S., Inspector of Local Boards, Madras.

Under the auspices of the Association, it is proposed to organise periodical lectures, seminars and symposia ; to offer to biologists, teaching and research institutions requisite information on marine biological matters ; to sponsor and organise scientific expeditions ; and to publish the JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, which will be the official organ of the Association. In addition to full length articles, the Journal will contain scientific notes of an original nature and a section—News and Comments—giving information on important marine biological and oceanographical items of current interest. A marine biological service has also been organized to help the visiting parties, details of which are given elsewhere in this issue.

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The response we have received from scientists and institutions from both within India and outside has been very encouraging. It is our earnest wish, that the scientific workers, particularly those who are engaged in marine biological and allied sciences, would endeavour to promote the ideals of the Association.

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THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

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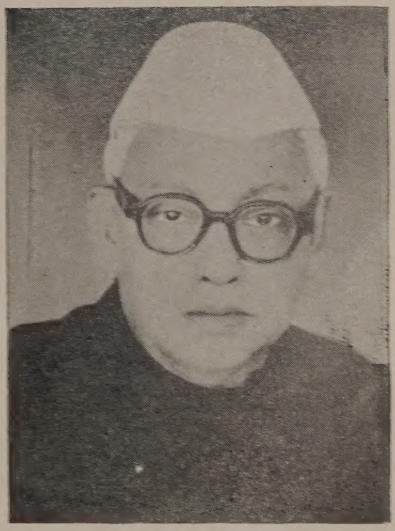
SECRETARIES

RAJ BHAVAN
Guindy, Madras-22

July 20, 1959



I am happy to know that the Marine Biological Association of India will be publishing the first issue of the Journal of the Marine Biological Association of India this month. I am told that this journal which will be published twice a year will contain scientific articles on marine biological and allied sciences relating to the Indian region. Our country has a long coast line and the marine resources remain inadequately explored for various reasons. An association for the pursuit of marine sciences and for raising the standard in the study of Marine Biology is very essential and the authorities are to be congratulated on this venture. I hope the inaugural issue which will contain articles from scientific workers in India and abroad, will give useful information to those engaged in the study of Marine Biology.

Bisnuram Medhi

(BISNURAM MEDHI)
Governor of Madras.

LOURDHAMMAL SIMON
Minister for Local
Administration and Fisheries

FORT ST. GEORGE
Madras

June 13, 1959

It gives me great pleasure to send this message for the first issue of the Journal of the Marine Biological Association of India—an organisation I had the good fortune to inaugurate on 3rd January 1959 at Mandapam. This Association, set up to promote and co-ordinate marine biological studies in India, is the first of its kind in the East. It is in the fitness of things that it has come to be established at Mandapam where the Central Marine Fisheries Research Station, the largest marine Fisheries Research Institute in South East Asia, is having its headquarters, in the centre of an area very richly endowed with marine life, attracting marine biological workers and students in large numbers from all parts of the country. Krusadi Island, known as marine biologists' 'paradise' where the Marine Biological Station of the Madras Fisheries Department is located is not far from here. I am happy to note the progress the Marine Biological Association of India has already made and the dynamic way in which it has begun to play a useful role in the scientific and educational activities of the country. I have every hope that it will grow from strength to strength and the Journal will meet a long-felt need. I wish the Association all success in promoting the publication of the Journal and thereby serving the cause of science.

L. Simon

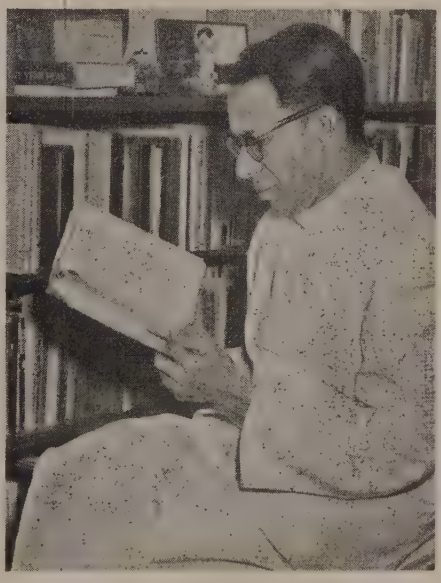
Minister for Local Administration and Fisheries.

सत्यमेव जयते

Minister
Scientific Research and Cultural Affairs, India
New Delhi

August 2, 1959

Marine Biology has not so far attracted as much attention in India as in some Western countries. A science which deals with the physical and chemical factors that operate and contribute to the sustenance of life in the wide oceans, it has yielded valuable and useful results in many Western countries. With our immense population and a limited acreage of arable land, India must pay increasing attention to sources of nutrition provided by her coastal waters. I am therefore glad to learn that prominent workers in this field of science have formed an association and hope that this will lead to greater interest in and more intensive study of Marine Biology in the country.



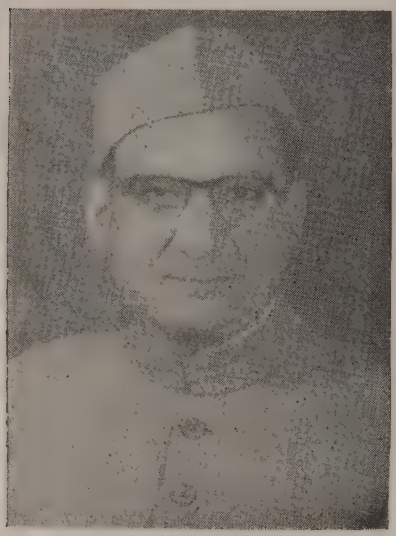
I am so glad to learn that the Association will bring out a journal devoted to studies in this specialised field. The scope of work is almost unlimited and very little has been done till now. I hope the journal will not only publish specialised articles dealing with original research but also provide a general forum for discussion among scientists who have made Marine Biology a special field of study.

(HUMAYUN KABIR)

The Aligarh Muslim University
Aligarh

4th July 1959

The recently founded Marine Biological Association of India marks an important phase in the development of fisheries research in our country. It corresponds not only to a period of growing interest in the subject but also to the time of our country's pressing demand of exploitation, conservation and management of fishery resources.



The seas and their resources have attracted increasing world attention in recent years. It is noteworthy that our Indian scientists are also taking such valuable steps towards the advancement of our knowledge about the Indian waters. I am very happy to welcome the inaugural issue of the Association's Journal.

I most sincerely congratulate the President of the Association on the production of such an outstanding Journal and wish the Association every success.

(Col. B. H. ZAIDI)
Vice-Chancellor.

ANNAMALAI UNIVERSITY
Annamalainagar P.O.
South India

28th June, 1959

I am glad to hear that the inaugural issue of the Marine Biological Association of India will soon be out. I wish the Journal every success.

The future achievements in biology will depend to a great extent on Marine Biological investigations. For, the sea is the original home of life and it is to marine organism that the Biologist has to turn for the fundamental as well as applied investigations in the Science of Life. India with its long coast line of about 3,000 miles provides excellent opportunities for marine biological studies. I am sure, the Journal of the Marine Biological Association of India will play a very important role in the advancement of marine biological research in India.

T. M. Narayanaswamy Pillai

(T. M. NARAYANASWAMY PILLAI)
Vice-Chancellor.

DIRECTOR GENERAL

Council of Scientific & Industrial Research
New Delhi

17-6-1959

I am glad to learn that the Marine Biological Association of India, which was formed recently, has decided to bring out a Journal. We have been, in recent years, paying a lot of attention to the development of various sciences in the country ; for many reasons, there has not been much of an advancement in Marine Biology and related sciences.

Not only I welcome the formation of the Marine Biological Association of India which, I am sure, will play a significant part in the advancement of the study of Marine Biology, but the Journal also, which should encourage contributions in the field of Marine Biology and developments in oceanography and should play an important role as a forum for discussion for all those who are interested in this discipline.

I wish your Association and Journal all success.

(M. S. THACKER)

THE INDIAN ACADEMY OF SCIENCES
Hebbal P.O., Bangalore-6
(South India)

16th July, 1959

Marine biology is a great subject in itself. Those of us who live on land do not always remember or realise that the ocean is a vast reservoir containing many varied and most fascinating forms of life. It is most fitting that the men of science in India who are actively interested in marine biology should band themselves into an Association and promote a journal which would be a forum for the publication of the results of their studies. It is very pleasing that the invitation to join the Association as Foundation Members has been so largely responded to. The success of the Association depends entirely on the enthusiasm and energy which its members bring to bear on their activities. I wish to convey my heartiest good wishes for the continued success of the Association and of its Journal.

C. V. Raman

(C. V. RAMAN)
President.

National Institute of Sciences of India
Mathura Road
New Delhi-1

15th July, 1959

I am glad to learn that the Marine Biological Association of India, which has been organized by workers actively interested in marine biological and allied sciences, proposes to publish a journal containing original contributions as well as important current news items on marine biology and oceanography. I have much pleasure in conveying my sincere congratulations and best wishes for the success of the new journal.

S. K. Mitra

(S. K. MITRA)
President,
National Institute of Sciences of India.

Journal of the
Marine Biological Association of India

ABBREVIATION : *J. Mar. biol. Ass. India*

VOL. I June 1959 No. 1

RESEARCH VESSEL *KALAVA* AND CO-OPERATIVE OCEANOGRAPHIC INVESTIGATIONS IN INDIAN WATERS

By S. JONES

Central Marine Fisheries Research Station, Mandapam Camp

INTRODUCTION

IT is a recognised fact that a knowledge of the environmental conditions and the reactions of fishes to the dynamics of oceanographic pattern is essential in predicting availability of fish in any area. But it is not easy to achieve this and the progress towards such an end is dependent on the intensity of work done and extent of co-ordination effected between the study of the two disciplines, oceanography, and fishery biology. The management of marine fisheries is a very complex and intricate subject, since the marine environment is never static and is continuously subjected to various influences brought about by currents, tides, etc. many of which have their source far away from the place where their ultimate effect is reflected on the fisheries. To cite an example, it is such background knowledge that has enabled the Norwegian research vessel G.O. *SARS* to guide fishermen with a remarkable degree of precision to schools of herring resulting in considerable saving in time and effort.

The need for a research vessel in connection with marine fisheries investigations in India was recognised from the very inception of the Central Marine Fisheries Research Station, but various practical difficulties stood in the way of procurement of one. In the early stages the investigations were confined mainly to the coastal belt availing of the existing types of craft. Gradually the work was extended wherever possible to areas further out with the help of trawlers of the Deep Sea Fishing Station. In 1957 oceanographic investigations were initiated by the Central Marine Fisheries Research Station in co-operation with the Indo-Norwegian Project and M.O. *KRISTENSEN* one of the fishing vessels of the latter was made available for this purpose, with Cochin as the base of operations. Research cruises were started in September 1957 but due to the unsatisfactory condition of the vessel it was condemned and replaced by its sister vessel, *KALAVA* (Plate I). Since the end of 1957 the vessel has been making regular oceanographic cruises along the West Coast of India.

R.V. *KALAVA*

The general plan of the vessel is given in the diagrams (Plate III). It was originally built in Norway as a whaling boat and later converted as a trawler and was first known as *FRAM* and then as *SULA*. When the Indo-Norwegian Project acquired it in 1954 its name was changed to *COCHIN* and subsequently it was renamed *KALAVA* in 1957. Details of the vessel :—

Length overall	..	20.25 m.
Breadth moulded	..	5.20 m.
Draught, bow	..	1.40 m.
.. aft	..	2.60 m.

Main engine 2 cyl. 120 H.P. ' Hjelset ' Semdiesel.
Aux. engine 2 cyl. 8 H.P. ' Lister ' diesel.
Speed maximum 8 knots per hour.
Bunkering capacity : Diesel oil 7 tons.
: Freshwater 3.5 tons.

The hull is plank built and covered over by copper sheath below the water line. The main deck is continuous. The crew's accommodation is at the fore part where there are 8 bunks for the purpose. Below the hatch is the fish hold and the stores for fishing gear. The refrigerating chamber with a capacity of 8,000 lbs. of fish is immediately behind the fish hold where all the provisions required for the cruises are kept.

In front of the main deck house and behind the hatch an improvised laboratory has been built with the entrance on the starboard side. The laboratory has a small work table with lockers and drawers below and racks for the chemicals and water bottles above. A writing board is fixed to the left entrance corner and two sleeping bunks are built on to the port side of the laboratory. Behind the galley are the entrances to the engine room which is comparatively spacious. The port side of the deck is enclosed and is used as the dining room. The hatch when closed could be used as a low platform for various purposes. The main mast is stepped on the fore deck and carries a derrick with a working load capacity of 2 metric tons.

The wheel house is provided with all the essential navigational equipment. It has a Robertson autopilot steering mechanism and a Simrad echosounder of white line recording type 513-2, 24 volts. In the chart-room behind are fitted a Philips radio direction finder, Simrad radio telephone, 70W, type 550-6, 24 volts having a range of about 200 miles and Simrad echosounder ' Barlodd ' type 512-1, 24 volts. Behind the chart-room and on the Starboard side is a small cabin with 2 bunks, for the captain and the engineer. The boat deck is on the port side of the wheel house where a life-boat for 12 persons is kept. On the Starboard side of the wheel house is a small sundeck. The auxiliary engine is coupled to the freezer and main engine to the hydraulic winches and the requisite current for normal lighting purposes is also supplied when the main engine is running. The auxiliary engine is also used for operating the main search light and for general lighting requirements. There is provision for using sail on both masts.

The boat is equipped for fishing cum research purposes and has both trawl and hydrographic winches which could be operated independently. The hydrographic

winch carries 2,500 metres of steel rope, dia. 3 mm. for operating water bottles (Plate II, 1) bathythermograph, plankton nets (Plate II, 2), etc. The hydrographic line is operated through a Bergen Nautik automatic meter wheel for recording accurately the depths at which collections are made.

The research vessel has on board various kinds of scientific equipment such as reversing water bottles, protected and unprotected thermometers, bathythermograph, plankton nets, trawls, grabs, etc., which are normally used for oceanographic investigations. Standard water bottles serially numbered are stored in special boxes. The vessel could continuously cruise for 15 days.

All the expenses for running the vessel and repairs to it are met by the Indo-Norwegian Project. It is manned by a skipper, an engineer, both Norwegians and an Indian crew of 9. From September 1957 to April 1958 and from October 1958 to May 1959 a physical oceanographer and a marine biologist respectively from Norway who were working as Research Advisers to the Project were regularly taking part in the cruises along with the scientific personnel of the Central Marine Fisheries Research Station.

Oceanographic Investigations

The area under regular investigation hitherto has been the southern section of the west coast from Cape Comorin in the south to near Mangalore in the north. The voyages to Mandapam for dry-docking purposes were taken advantage of for making collections from the Gulf of Mannar. In addition to the above, three cruises to the Laccadive Archipelago were made on an oceanographic cum fishery resources survey of the area. It is needless to mention here that the Laccadive Sea with its special ecological conditions is likely to have considerable influence on the adjacent coastal waters of the mainland of India and any development of the latent fishery resources of the Laccadives could most effectively be carried out only with the ports of Kerala as the base. The stations covered so far are indicated in Plate IV.

It is only about a year and a half since the cruises have been under way and the biological collections are being studied and oceanographic data are being processed. Some points of special interest are mentioned below.

Oceanographical studies in the area between Cape Comorin and 65 miles south of Mangalore showed certain very interesting features (Ramasastry—MS, and Ramasastry and Myrland—MS). (1) It was found that the pattern of temperature distribution in most cases (except during the colder months) is bimodal or multimodal. (2) During the south-west monsoon upwelling takes place along this coast when the surface water is displaced by subsurface water. Almost a complete turning over takes place during the process of upwelling and is spread over the entire continental shelf. The amount of water drawn from the subsurface layers varies with the intensity of upwelling but in general the upper 100 m. of the subsurface water interacts in this process. The deeper water rises vertically to some extent but never up to the very surface. (3) In the south-eastern Arabian Sea three major water masses have been recognised in the upper 300 m. of the sea (a) The Arabian Sea surface water, (b) the Arabian Sea upper subsurface water, and (c) The Arabian Sea lower subsurface water. (4) The investigations have revealed the mixing of the Indian

Equatorial water, which is found between 200 and 2,000 m. with the Red Sea Water, a process very much similar to the mixing of the Mediterranean water with the Atlantic water. This mixing presumably results in the formation of the intermediate deep water masses in the Arabian Sea. (5) In the Laccadive Sea comparatively low salinity water is found during the dry months. This may indicate the presence of the subantarctic bottom drift. (6) Prominent eddy circulations have been noticed between Alleppey and Quilon and in the vicinity of Calicut. (7) The data collected on aspects such as divergence, convergence, upwelling, and circulation have given certain clues for a better understanding of the dynamics of the mud bank formation. (8) The circulation pattern and thermal structure show that the region off Calicut serves as a transition zone between the northern and southern water masses.

Velocity of sound in the Arabian Sea along the south-west coast of India during the post-monsoon season has been studied (Ramasastry and Ramamirtham—MS). A sound channel running westwards from Quilon to about 30 miles and then turning northwards is found between 10 m. and 50 m. depth. At greater depths this channel seems to have an eastward branch with other isopleths converging with it at 9° N.

The upwelling along the south-west coast of India during the south-west monsoon appears to have considerable influence on the coastal fisheries there (Banse, 1959). The upwelling water has low oxygen content and as such this area is avoided by fish which move to either comparatively shallow water or to deeper zone. The high phosphate figures of the surface waters in this area during this time also appears to be mainly due to upwelling. The vertical distribution of dissolved oxygen during summer months in the deep waters of the Arabian Sea in the neighbourhood of the Laccadive Islands has been studied (Jayaraman *et al.*—MS) and it has been found that the surface layer upto a depth of 50 m. has a more or less uniform oxygen content from whence there is a rapid decrease with the lowest values at about 150 m. depth and again a rising trend from about 700 m. downwards.

Planktologically the area is extremely rich both in the number of species, and the abundance of organisms. Most of the forms present are holoplanktonic because a majority of the samples are collected far away from the coastal areas. However, larval forms, particularly of decapods are common. In this connection mention may be made of the several phyllosoma larvae obtained from the Laccadive-Minicoy region belonging to the species of *Panilurus* (Prasad and Tampi—unpublished). A few phyllosoma of *Scyllarus* spp. were also obtained. Pteropods and a variety of hydromedusae are common in many samples. Several species of Larvaceae and Thaliaceae are abundant and so also the Siphonophores. Chaetognaths form another important group. About 13 species of *Sagitta*, 2 species of *Eukrohnia*, 2 species of *Krohnitta*, and *Pterosagitta* have been recorded (Prasad & Reddy—unpublished). Samples collected from the Minicoy area occasionally showed a fairly large number of the young ones of *Amphioxus*. In all the plankton samples copepods undoubtedly dominate and of these the Calanoids are predominant. However, in a few samples enormous numbers of the red Harpacticoid. *Metis jousseanmei* are found.

During some of the cruises extensive patches of *Trichodesmium* were encountered in the open sea.

Very valuable information has been collected about the fisheries around the various islands during the special cruises to the Laccadives. A study has been

made particularly of the tuna fishery of Minicoy (Jones, 1958*a*, Jones and Kumaran, 1959). A study of the bait fishes on which the fishery of the oceanic skipjack depends has been initiated with a view to determine their distribution and abundance. *Spratelloides delicatulus* has been noticed near certain islands and its utility as a potential bait fish for tuna fishing deserves investigations. A general collection of fishes has been made which includes several species not previously recorded from the area. Some of these like *Gemphylus serpens* are oceanic species while a few deep sea forms are also represented. The presence of swordfish, and sailfish, the larval stages of which have already been described (Jones, 1958*a*, and 1959) and a variety of other fishes indicates the scope for the development of a potential sport fish industry, with Cochin as the base, for the above highly prized fishes.

The collections of larval fishes from the Laccadive Sea are of special interest. Occurrence of larvae of fishes such as *Xiphias gladius*, *Istiophorus gladius*, *Katsuwonus pelamis*, *Neothunnus macropterus*, *Euthynnus affinis*, and *Auxis* show that this area forms an extensive breeding place for the above economically important fishes (Jones, MS). The eggs and larval stages of a number of Synentognathi have also been obtained and the material is being worked out.

Indian Ocean continues to remain the largest unknown water mass and an international assault on it is contemplated in 1961 under the auspices of the UNESCO. It is hoped that R.V. *KALAVA* despite its limitations will be able to contribute its share in this co-operative effort. With increased mechanisation of fishing craft and consequent greater range in fishing operations, the marine resources of India are being exploited more and more. Considerable expansion is envisaged under the third five-year plan requiring a large number of trained personnel for research and development. In this connection R.V. *KALAVA* is also serving the dual purpose of a training cum research vessel for the technical personnel recruited in connection with marine fisheries research in this country.

The work of R.V. *KALAVA* is a demonstration of international co-operation on a miniature scale. The investigations initiated by the Central Marine Fisheries Research Station in co-operation with the Indo-Norwegian Project have helped to open a new chapter in the annals of oceanographic research in general and fisheries research in particular in Indian waters.

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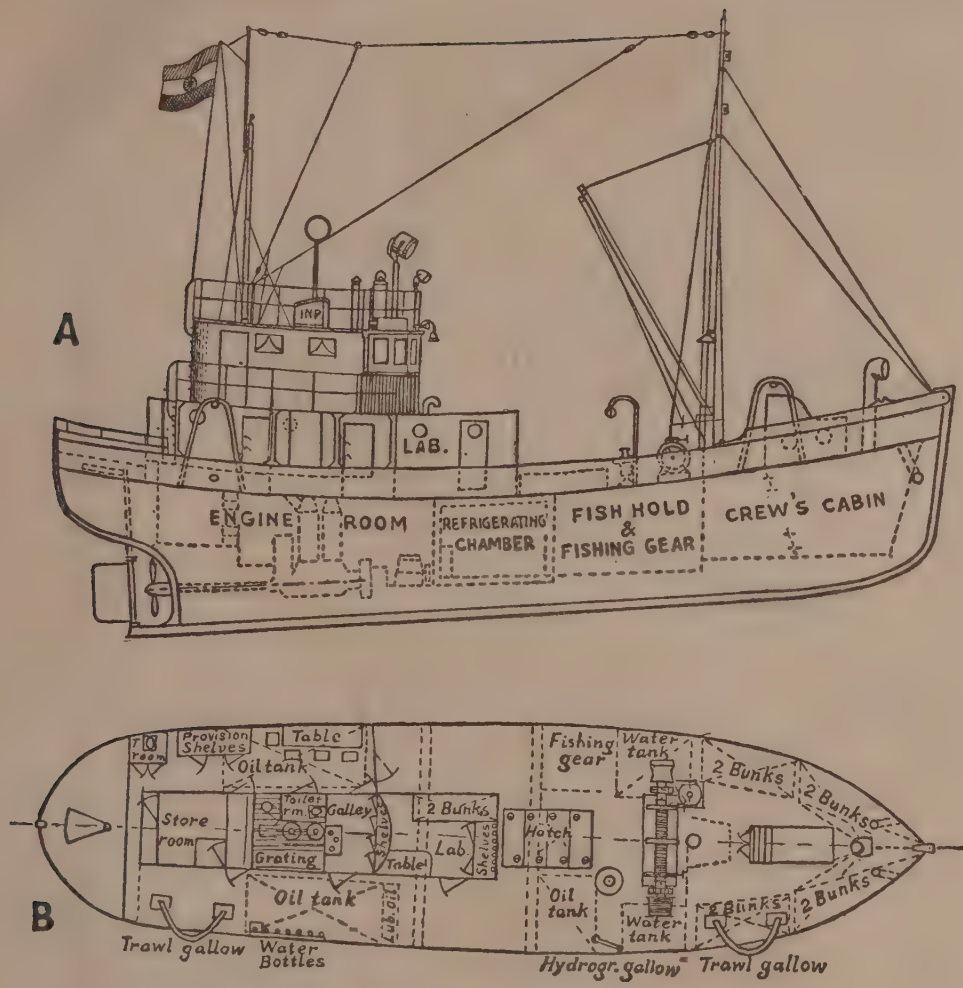
R.V. *KALAVA*

Fig. 1. Operation of reversing water bottle.

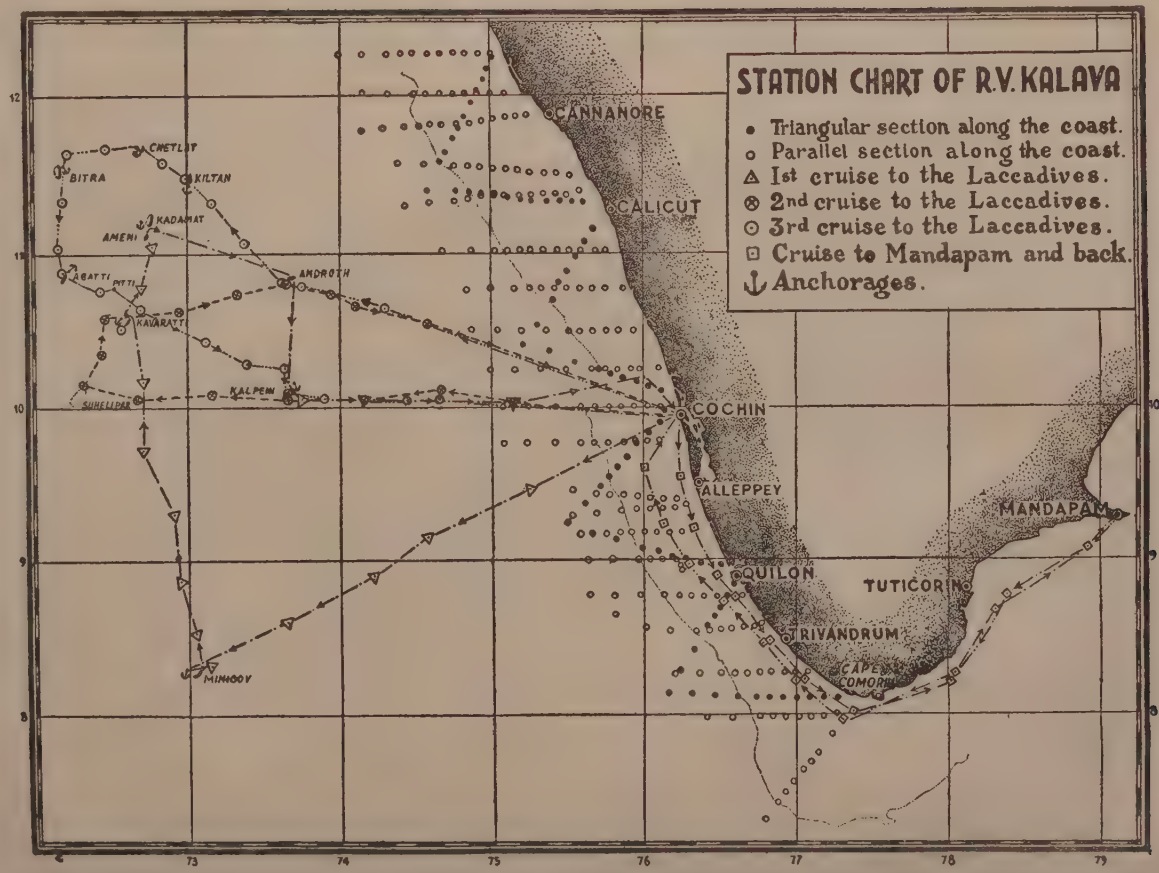
Fig. 2. Plankton haul.



R.V. KALAVA

A. PROFILE
B. MAIN DECK PLAN
C. BOAT DECK & WHEELHOUSE PLAN

By courtesy of Indo-Norwegian Project


STATION CHART OF R.V. KALAVA
• Triangular section along the coast.
o Parallel section along the coast.
△ 1st cruise to the Laccadives.
⊗ 2nd cruise to the Laccadives.
⊙ 3rd cruise to the Laccadives.
⊡ Cruise to Mandapam and back.
⚓ Anchorages.
CANNANORE
CALICUT
COCHIN
ALLEPPEY
QUILON
TUTICORIN
TRIVANDRUM
MANDAPAM
CAPE COMORIN
CHETLAT
BITRA
KILTAN
KADAMAT
AMENI
ANDROTH
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J. Mar. biol. Ass. India, 1959, **1** (1) : 7-12

PRIMARY PRODUCTION IN TROPICAL MARINE AREAS

By E. Steemann Nielsen

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Most studies of marine primary production have been carried out in temperate or arctic water. The location of most marine institutes, together with the sites of the world's biggest fisheries, is of course one of the main reasons for this fact. It would be wrong, however, to assert that the tropical parts of the open oceans are particularly little known concerning primary production. These regions are in fact those best understood at present. The German Expeditions during the first third of this century—the *Deutschland* and the *Meteor* Expeditions—provided the fundamental knowledge concerning the size of the standing stock of phytoplankton in these waters. These were followed by the Danish *Galathea* Expedition in 1950-52 where the organic productivity was measured by means of the carbon-14 technique. In recent years the work in the open oceans has been greatly intensified.

In this article only the primary production by the marine phytoplankton will be discussed. The production caused by sessile microscopic and macroscopic plants living near the coast generally follows the rules valid for the phytoplankton. The carbon-14 technique (Steemann Nielsen, 1952) has rendered it possible to measure the rate of organic production by the phytoplankton, whether it is high or low.

It is always problematical to generalize about the magnitude of the primary production in the sea. It would at least be rather difficult to establish well-defined regions according to temperature. Cold marine areas may be either very productive or very unproductive. The same is true of the really warm regions of the sea.

Temperature as such can thus hardly be a factor of general decisive importance for the size of primary production. We shall provide evidence that the influence of temperature on the size of primary production is indirect. A high temperature may be the real cause of a rich production in some areas, whereas it is of very little importance in other areas.

Another characteristic of tropical marine areas is the ordinary high intensity of light penetrating the surface. If the light intensity were the ordinary limiting factor for marine organic productivity, all tropical marine areas would be very productive. However, only a small and varying part of the light reaching the sea surface is transformed into chemical energy by the plants. The major part of light is ordinarily not absorbed by the plants but by the water itself, by suspended dead organic and inorganic particles and by dissolved matter.

Generally the principal factor limiting the magnitude of organic production in the sea is the replenishment of the nutrients in the productive euphotic layer (*cf.* for example Steemann Nielsen and Aabye Jensen, 1957). The replenishment of the nutrients—primarily phosphate and nitrate (or ammonia) is provided by the two processes of decomposition and water circulation.

In general, it may be stated that in the open deep ocean replenishment by water circulation is by far the most important process, whereas in such coastal areas where the water in the photic zone is more or less regularly in contact with the bottom, microbiological decomposition of organic matter is the most important factor. Due to this decomposition, the salts containing phosphorus and nitrogen are regenerated. In the open ocean and in shallow water, organic productivity is thus governed in a different way.

The Production in the Open Oceans

Sverdrup (1955, Fig. 2) has presented a schematic picture of the probable relative productivity of ocean areas, based entirely on theoretical considerations. In the areas where either intensive measurements of the standing stock of phytoplankton have been made, such as in virtually the whole of the Atlantic ocean, or where measurements of the primary production have been made, a remarkable agreement with Sverdrup's theoretical picture is found. Sverdrup's theoretical considerations were based on the idea that the size of the primary production in the open ocean is dependent primarily on the rate of replenishment of the nutrient salts through the supply of subsurface water to the photosynthetic zone, as was shown convincingly in the South Atlantic by the *Meteor* Expedition (Hentschel and Wattenberg, 1930).

A common feature, especially obvious in the tropical and subtropical parts of the oceans, is the low range of variations of the values obtained within areas which are hydrographically uniform. This is true both for the plankton counts, carried out on a very big scale by the German expeditions—(*cf.* Lohmann, 1920 ; and Hentschel, 1933-36), and for the measurements of organic production as carried out in the later years by means of the carbon-14 technique.

It is possible to give a hydrographical outline corresponding, in general terms, to the conditions found in all oceans (for details *cf.* Sverdrup *et al.*, 1942). All oceans are characterized by large circulating current systems. In the South Atlantic, the South Pacific and the Indian Ocean these run counterclockwise. An anticyclonic eddy is found in the center of the currents. The current in each ocean flowing across the oceans south of Equator from East to West is called the South Equatorial Current. In contrast to the oceans of the southern hemisphere the anticyclonic eddies in the North Atlantic and in the North Pacific are clockwise. The North Equatorial Currents are thus also running from East to West.

In all oceans an eastgoing Counter Current is found between the North Equatorial and the South Equatorial Currents, both running in a westerly direction. Due to the shape of the Indian Ocean the current system in the northern part only partly resembles those found in the North Atlantic and the North Pacific. The west-going North Equatorial Current is found only during part of the year. It is neutralized or substituted by an eastgoing current when the South West Monsoon is blowing.

Theoretically a low productivity is to be expected in lower latitudes in the central part of the anticyclonic eddies. Here the surface water is slowly sinking downwards thus preventing any admixture of subsurface water to the photic zone. The renewal

of the plant nutrients in the surface water takes place by decomposition *in situ* of organic matter or by lateral influx of surface water, already impoverished with regard to nutrient salts. On the other hand, high productivity is found in localities where upwelling takes place, for example, associated with diverging surface currents. At the boundary between the South Equatorial Current and the Countercurrent in the eastern parts of all three oceans, especially well developed divergences are found.

According to Brandhorst (1958), in tropical oceanic waters there is an inverse relationship between the depth of the thermocline and the size of the standing crop of zooplankton—and thus also with the magnitude of the primary production. In the tropical ocean, outside areas with upwelling, a strong thermocline is found throughout the year. As ordinarily no seasonal turnover of the water column takes place, the availability of the nutrient salts to the plants—the factor governing the size of the primary production—is dependent largely upon the depth of the thermocline.

The depth of the thermocline varies much within tropical oceanic waters. Accordingly the rate of the primary production also varies a great deal. Whereas the daily rate is about 50 mg. C/m.^{2} near the centres of the anticyclonic eddies corresponding to a depth of the thermocline of more than 100 metres, it increases in other parts of the oceans to values about 500 mg. C/m.^{2}. Near true upwelling, the rate may be considerably higher (*cf.* Steemann Nielsen and Aabye Jensen, 1957).

The simplest way to estimate oceanic production is by means of the colour of the sea. The deep blue water is the most unproductive water. The transparency of the water is, of course, a better indication of productivity. The more transparent the water, the greater is the depth of the photosynthetic layer and the smaller is consequently the part of the incident light which is absorbed by the plankton algae. The clearest, deep blue water with a very small stock of algae behaves in this respect virtually like distilled water.

It is possible at present to outline the general pattern of oceanic primary production in the tropics. The details, however, are still missing. A lot of work must be done before these become known. If investigations on primary production are to be used as a basis for evaluating the possibilities, for example, of a commercial fishery, it is absolutely necessary to know the details. Special parts of the oceans, such as the Bay of Bengal and the Arabian Sea in the Indian Ocean especially demand intensified studies, not only because of the influence of the monsoon shift in such areas but also because of the special importance of increasing the fishery here.

The Production in Tropical Coastal Areas

Much too little is known concerning the organic production in tropical coastal areas. It is nevertheless possible to present some general outlines. Whereas in the open ocean the replenishment of the nutrients and thus productivity is governed primarily through admixture to the photosynthetic zone of nutrient-rich subsurface water in which the regeneration of the salts has taken place long ago, in coastal waters the replenishment is first and foremost due to regeneration taking place simultaneously.

Present knowledge seems to indicate that the regeneration of the nutrient salts in coastal waters takes place primarily in the surface of the bottom sediments. If the depth is inconsiderable the water masses of the photosynthetic zone will be in more or less continual contact with the bottom and the replenishment of the nutrient salts will be easy. If a layer of discontinuity of some kind is found, the admixture of the nutrients to the surface layer becomes somewhat more complicated. All available evidence suggests that the regeneration rate of the nutrient salts is dependent on temperature. The higher the temperature, the higher the rate. This is in accordance with the fact, that the regeneration is due primarily to microbiological processes. The rate of metabolism in bacteria is dependent on temperature.

As demonstrated during the *Galathea* Expedition. (Steemann Nielsen and Aabye Jensen, 1957) a relatively high rate of organic production was found at practically all coastal stations in the tropics. This is in agreement with the theoretical considerations presented above. The only exception was found near the mouth of the Congo River where the low transparency of the water masses due to the silt brought down with the river water caused very poor light conditions for the phytoplankton and thus a very low production rate.

The seasonal variation of the primary production in coastal waters in the temperate zone provides additional evidence for the thesis that temperature is the most important factor governing the size of primary production in water masses in contact with the bottom. In Danish waters a large number of such localities have now been investigated all of which show a close correlation between the rate of primary production and temperature (*cf.* for example, Fig. 6 in Grøntved and Steemann Nielsen, 1957). For one area where regular investigations have been carried out during several years it has been possible to correlate the rate of primary production during the summer with the temperature (Steemann Nielsen, 1958).

Even close to the coasts of isolated islands in the tropical parts of the oceans a relatively high rate of organic production is ordinarily found. Doty and Oguri (1957) have shown this to be true for the Hawaii Islands, which are situated in an oligotrophic part of the Pacific.

Details of coastal productivity in the Tropics are still lacking. We may perhaps suggest that they are as varied as those found in similar areas at higher latitudes.

Temperature and the Production of Organic Matter in Plankton Algae

Enzymatic processes are dependent on temperature. In plankton algae respiration and photosynthesis at higher light intensities are thus also dependent on temperature. If algae are transferred to a higher temperature the rates of both processes automatically increase. It is thus easy to understand that several scientists have got the idea that the rate of metabolism is much higher in tropical than in colder waters. This very idea was presented by the present writer concerning the bacteria active in the regeneration of the nutrient salts.

However, we shall try to show that the bacteria represent a special case. Ordinarily—and thus in the case of plankton algae—the metabolism seems by no means

to be higher in tropical than in temperate and arctic waters (*cf.* Steemann Nielsen and Hansen, 1959, for details). The rate of an enzymatic process is a combined result of enzyme concentration and temperature. If the temperature is low, the effect may be completely counteracted if the enzyme concentration is high. In Nature most kinds of organisms able to live in a certain habitat seem to be capable of adjusting their enzyme concentration at a level most appropriate to the prevailing ecological conditions in that habitat.

In organisms like the autotrophic plankton algae containing for example relatively big chloroplasts, the enzymes constitute only a minor part of the organic matter found. Thus a considerable augmentation of the concentration of enzymes does not cause a considerable increase in the amount of total organic matter per cell. In bacteria, on the other hand, a major part of the dry substances ordinarily consists of protoplasmic proteins, most of which must be considered to be enzymes in the widest sense. If the content of enzymes, in order to counteract a decrease in temperature, has to increase by a factor of say 2, the content of total organic matter will also increase considerably. Although the rate of the different metabolic processes increases per cell when the contents of the enzymes are augmented, relatively much more organic matter must now be produced in order to reproduce the bacteria. It is thus not possible to keep the reproduction time constant in bacteria at a low temperature by simply increasing the concentration of the enzymes.

As shown in the preceding section, the bacterial regeneration rate of the nutrient salts is the main factor governing primary production in coastal waters. The apparently astonishing fact is therefore found, that production here is strongly dependent on temperature, although the direct influence of this factor on phytoplankton growth is rather insignificant. We obtain thus the background for understanding why temperature is an important factor for the size of the production in coastal waters but not in the open ocean, where the replenishment of the nutrient salts is not primarily due to the regeneration *in situ* of these salts.

Summary

An outline of the primary production in tropical waters is presented. It is shown that the replenishment of the nutrient salts ordinarily governs the size of the production both in the open sea and in coastal waters. Whereas in the open sea this replenishment is provided primarily by water circulation, in shallow coastal waters it is provided by decomposition taking place primarily in the upper layers of the bottom sediments. Because the decomposition is due to microbiological processes it is dependent on temperature. The water circulation in the open sea, on the other hand, is not dependent on temperature. Hence this factor is of quite different importance in the two habitats.

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LABORATORY EXPERIMENTS ON SOME FACTORS AFFECTING THE SURVIVAL OF MARINE TELEOST LARVAE*

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Introduction

There has been remarkably little precise experimental work upon the conditions necessary for the successful rearing of marine larval fish. The experiments described here were therefore undertaken as part of a study of the biology of the common shore fish *Blennius pholis* L. and *Centronotus gunnellus* (L.) (Qasim, 1956 *a*, *b*, 1957 *a*, *b*). A preliminary report of the initial experiments (Qasim, 1955) has already revealed the necessity of providing suitable conditions, not only of food, but of diurnal changes in illumination. The present account describes another series of experiments subsequently undertaken to investigate the influence of food, light, water agitation and temperature on the survival of larvae of the two species. In addition to these factors, there are observations on the 'gas disease', noticed in various species by many authors and attributed by some to supersaturation of water with gases (Soleim, 1940 ; Dannevig & Dannevig, 1950 ; Henly, 1952).

Material and Methods

Large number of egg masses of *B. pholis* and *C. gunnellus*, generally with advanced stages of embryonic development were collected from between the tide marks by turning over stones and transferred to glass tanks in the laboratory. Here, they were kept well aerated and provided with continuously running sea water. On hatching, fairly equal numbers of larvae were distributed between several similar jars, each containing about 25 litres of sea water. This water was well circulated by streams of air bubbles. Parallel experiments were then set up in which batches of larvae were exposed to different conditions, the influence of which is discussed below. In each series of experiments, conditions other than those under investigation were kept identical in all jars, as far as possible. For example, in experiments dealing with food, changes of water were carried out similarly in all the jars, and in experiments with light, all jars were provided with running sea water. To obtain significant data from each experiment, at least three replicate jars were used for each condition investigated.

Moderate quantities of food were added to the experimental jars, generally twice a day. At the same time the larvae which had died were removed

* The experimental work described in this paper was carried out at the Marine Biology Station, University College of North Wales, Bangor, U.K.

and their numbers from each jar were recorded. Most of the experiments were carried out in an underground aquarium room, where the fluctuations in daily temperature were not more than 1°C (usually much less) and the seasonal changes in temperature were only slightly greater than those in the Menai Straits.

Nutritional Value of Some Phytoplankton Cultures

Probably the most important factor in rearing larvae is the provision of suitable food. Until the present work was undertaken there was little evidence available to show to what extent fish larvae can meet their needs for normal growth directly from the phytoplankton. Detailed studies of gut contents of many species of young fish taken in tow-nettings revealed the presence of diatoms and green plant remains which, together with copepods and other Entomostracea, appear to form a considerable proportion of their food (Lebour, 1918-22). Gross (1937) fed young herring on phytoplankton cultures, but the findings of other authors based on observations in nature as well as in aquaria have indicated that phytoplankton is of poor food value to young fishes (Soleim, 1942 ; Dannevig, 1947). Other authors, however, have held that even dissolved organic matter may provide them with some nutrition (Morris, 1955).

In previous experiments (Qasim, 1955) marine fish larvae were observed to ingest large numbers of diatoms and flagellates as a result of the regular swallowing of water which forms part of the mechanism of osmoregulation (Smith, 1932 ; Keys, 1933). The survival rate of *Blennius pholis* larvae, however, in jars containing *Chlamydomonas* sp. and *Isochrysis galbana* Parke, two flagellates, generally considered to be valuable food organisms to invertebrate larvae, was only slightly greater than those kept in jars without food (Qasim, 1955).

To investigate further the relative importance of these food organisms, this experiment was first repeated by offering the same two flagellates (*Chlamydomonas* and *Isochrysis*) in a mixed state to 50 larvae of another shore fish, *C. gunnellus*. The same number of larvae was kept in each of three similar jars without food. To ensure, as far as possible, that the larvae did not get any extraneous food, the sea water used in all six jars was previously passed through sintered glass filters. The survival rate of the total number of larvae under these two conditions is shown by the curves A and B in Fig. 1. It can be seen that the larvae fed on flagellates showed slightly better survival than those kept without food. The difference seemed significant, for there was good agreement between replicates of both experimental and control jars. When in a later group of experiments each of the two species of flagellates were offered separately, the survival rate was again better with flagellates, the difference being slightly more marked in jars containing *Isochrysis* (Fig. 2, A, B and C). *Isochrysis* has previously been shown to be a very good food for oyster larvae (Port Erin *Flagellate* I in Bruce, Knight & Parke, 1940).

A comparison of the survival of the larvae kept without food, as controls in the two experiments, will indicate that those of the later experiment survived slightly longer than those of the earlier one. This is probably because the eggs of *C. gunnellus*, when collected with advanced embryos late in the breeding season, begin to hatch immediately. Since this hatching is probably due to some mechanical stimulus, such as shaking, as in *B. pholis*, (Qasim, 1956b), it is probable that the larvae used

in the latter experiment had greater supplies of yolk left, which enabled them to survive longer.

Further investigations on the food value of flagellates with larvae of *B. pholis* gave similar results (Fig. 3, A, B and C), the larvae showing slightly better

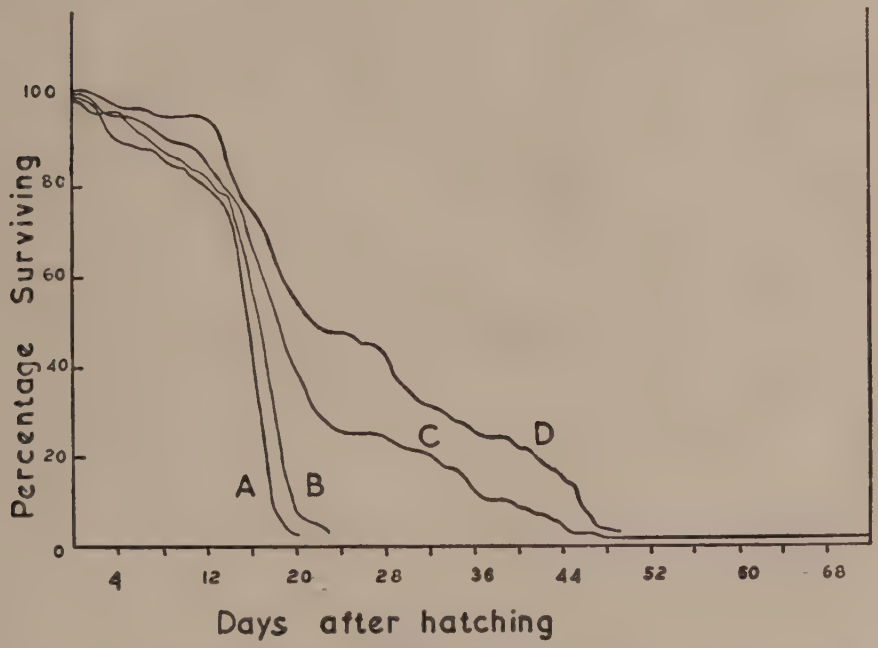

FIG. 1. Percentage of larvae of *C. gunnellus* surviving at the end of each day, when kept under different conditions of food. All larvae were given continuous illumination. A, without food ; B, with flagellates ; C, with *Artemia* nauplii ; D, with *Artemia* nauplii and flagellates.

survival when fed on *Isochrysis*. The consistency in the results of all these experiments clearly suggests that the flagellates have some slight value as food, but the effect is not conducive to much greater longevity.

Larvae fed on nauplii of *Artemia* or *Balanus* survived much longer. They grew fairly rapidly and a small percentage continued to survive until metamorphosis. Each species, when young, showed its own characteristic behaviour of catching the nauplii. Larvae of *B. pholis*, which have no external yolk sac, generally began feeding on nauplii within 24 hours after hatching, whereas larvae of *C. gunnellus*, which have a small external yolk sac, did not start feeding until about 2-3 days old.

The question then arose, as to whether the survival rate would be improved by the initial ingestion of flagellates, as a result of osmoregulation, before feeding

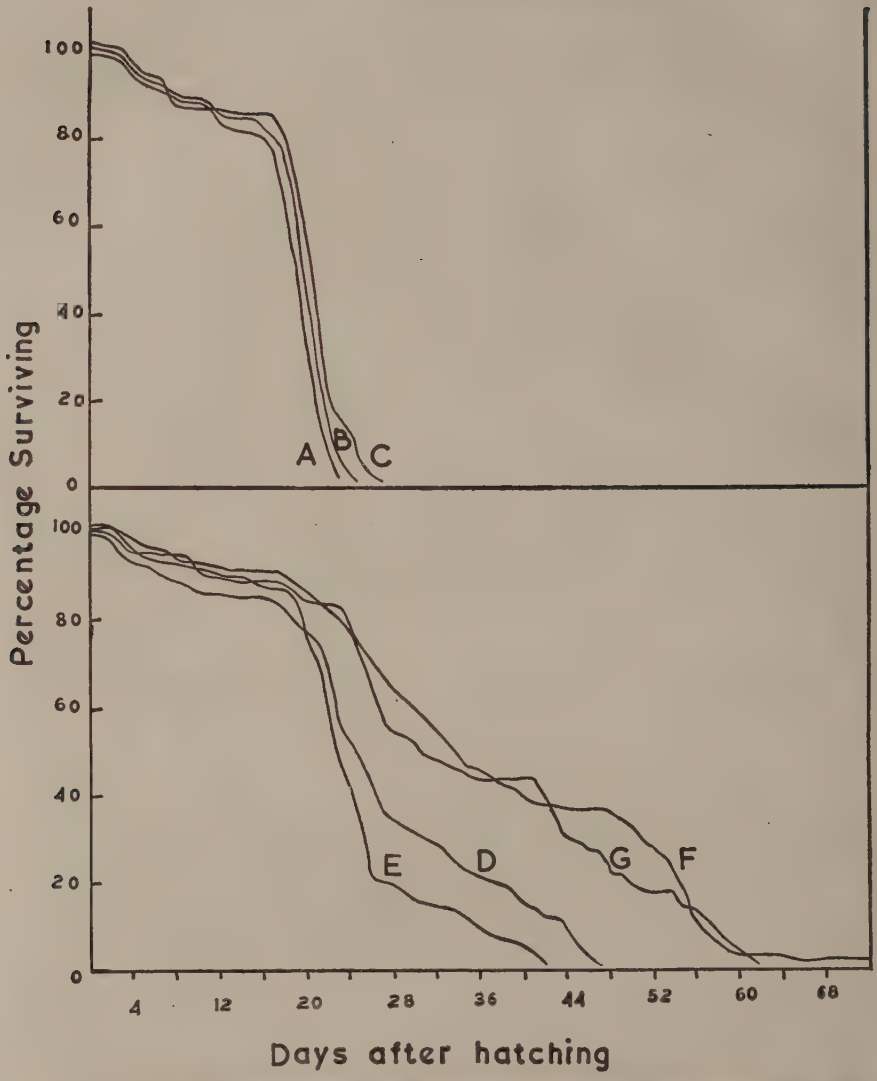

FIG. 2. Percentage of larvae of *C. gunnellus* surviving at the end of each day, when kept under different conditions of food and illumination. A, without food, continuous light; B, with *Chlamydomonas*, continuous light; C, with *Isochrysis*, continuous light; D, with *Artemia* nauplii, continuous light; E, with *Artemia* nauplii and flagellates, continuous light; F, with *Artemia* nauplii, alternate light and darkness; G, with *Artemia* nauplii and flagellates, alternate light and darkness.

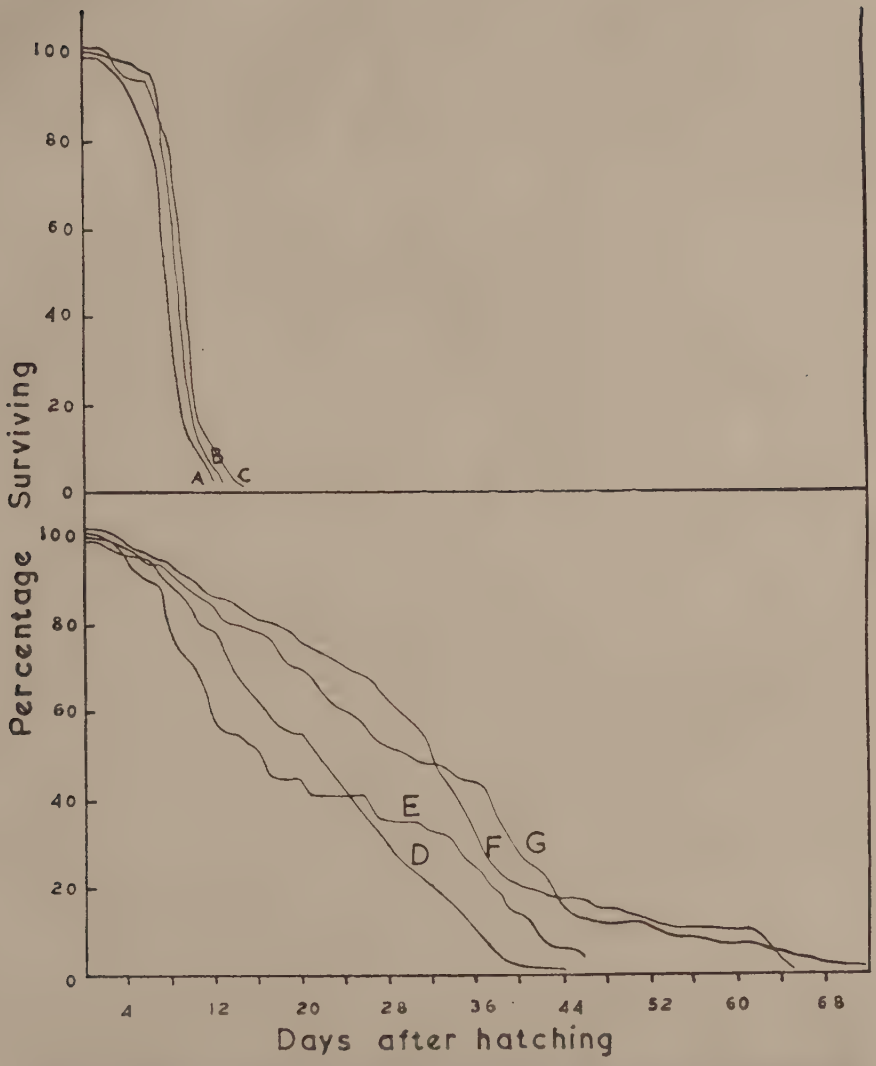

FIG. 3. Percentage of larvae of *B. pholis* surviving at the end of each day, when kept under different conditions of food and illumination. A, without food, continuous light; B, with *Chlamydomonas*, continuous light; C, with *Isochrysis*, continuous light; D, with *Artemia* nauplii, continuous light; E, with *Artemia* nauplii and flagellates, continuous light; F, with *Artemia* nauplii, alternate light and darkness; G, with *Artemia* nauplii and flagellates, alternate light and darkness.

on nauplii began. This was investigated by feeding the larvae, from hatching onwards, with a mixture of *Artemia* nauplii and flagellates. Controls were fed with *Artemia* nauplii alone. In the first series of experiments, larvae of *C. gunnellus* fed on such a mixed diet showed somewhat better survival than those fed on *Artemia* nauplii alone (Fig. 1, C and D). But later more detailed experiments failed to confirm this (compare survival curve E with D, and G with F, in Fig. 2). Similarly, with larvae of *B. pholis*, mixing flagellates with nauplii used as food produced no significantly better survival (Fig. 3, E and D ; G and F). Evidently flagellates are of very little direct food value to these fishes.

Diurnal Changes in Illumination

Other factors including light are of importance in rearing. The influence of these factors upon the survival of cod larvae has been investigated fairly extensively by Dannevig (1932) and by Dannevig & Sivertsen (1933), while Shelbourne (1953) has shown that young plaice take food only in the light.

It soon became evident from early experiments that *B. pholis* behaved similarly ; in complete darkness it stopped feeding, became inactive and eventually died, presumably from starvation. If, after being kept in the dark for a while, the larvae were again exposed to light, they became very active, and showed more intensive feeding on nauplii than did larvae which had been kept continuously under illumination. By giving alternate periods of light and darkness, it was possible to obtain better survival rates throughout the experiment than by giving continuous illumination (Qasim, 1955). Further experiments on the influence of light on the survival of *B. pholis* abundantly confirmed this. Several jars containing larvae of *B. pholis* were exposed to 7-8 hours of light during the day and were covered with thick black cloth during the night. The same number of jars were kept under continuous light. During illumination, the sources of light were fluorescent tubes in both cases. The survival rate of the total number of larvae contained in all jars under each of these two conditions is shown in Fig. 3. The two curves D and E in Fig. 3 represent two different kinds of food, *Artemia* nauplii and *Artemia* nauplii plus flagellates respectively, kept under continuous illumination, whereas F and G represent similar food conditions, kept under alternating periods of light and darkness. On comparing the survival curves, it will become evident that, under both food conditions, the larvae given alternate periods of light and darkness survived better than those kept under continuous illumination. Similar results under these conditions of food and light were obtained with larvae of *C. gunnellus* (Fig. 2, D, E, F and G).

Water Agitation

In early experiments glass plunger plates were used to stir the water, as advocated by Garstang (1900) and Lebour (1923), but heavy mortalities followed and it seemed that larvae were being injured by sharp edges of the plates. It was not thought advisable to continue plunger-jar experiments with smoother plates, since observations on the behaviour of the larvae suggested that they were unfavourably disturbed whenever the plungers were set in motion. The air bubbles, used for stirring thereafter, seemed to distrub the larvae far less. The steady circulation of water set up allowed the nauplii to congregate in certain places, generally nearest the light, where

FIG. 4. A closed bubbler which consists of a narrow glass tube enclosed by a wider tube resting on the curved lower end of the former. The lower end is covered with plankton silk.

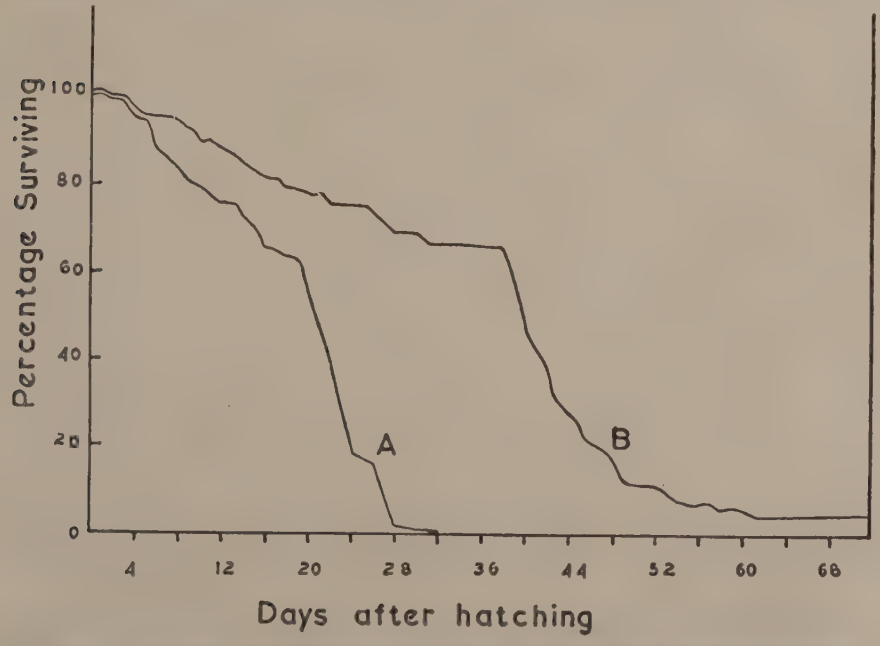

FIG. 5. Percentage of larvae surviving at the end of each day, when kept in jars provided with two different methods of air bubbling. A, closed bubblers ; B, open bubblers.

they were easily caught by the fish larvae. Occasionally, however, larvae would be caught in the streams of air bubbles and carried upwards rather violently.

To test the possibility that such occasional disturbance by the bubbles might be unfavourable, the following experiment was carried out with larvae of *B. pholis*. A bubbling method was devised, which caused very little disturbance but gave apparently adequate circulation of water. Compressed air was blown into the water down a narrow glass tube with a recurved lower end. This tube was totally enclosed in a wider tube, which had its lower end covered with plankton silk to prevent entry of larvae. The open upper end of the wide tube projected about one inch above the water level in the jar. In operation, water was drawn from the bottom of the jar into the lower end of the wide tube, where aeration took place, and the aerated water trickled steadily from the upper end under the propulsion of the rising bubbles of air (Fig. 4). These special aerators were called 'closed bubblers' to distinguish them from the ordinary 'open bubbler' which allowed the larvae direct access to the rising stream of air bubbles.

Five jars with about 30 larvae in each were provided with such closed bubblers and the same number were kept bubbled rather hard with open bubblers. Alternate day and night illumination was given to all jars and *Artemia* nauplii were provided as food. The survival rate of the total number of larvae under each of these two conditions is shown in Fig. 5 (A and B). There was good agreement between the replicates.

It can be seen from Fig. 5 that in the jars provided with open bubblers, the larvae survived much longer than those bubbled by the closed method. They also grew much more quickly. Ordinary bubbling would appear to be not only the simplest method of aeration, but also the best.

Temperature Tolerances of Larvae and Embryos

Previous authors have shown that the ability of adult fish to resist extreme ranges of temperature varies greatly from species to species (Britton, 1924 ; Hathaway, 1927 ; Doudoroff, 1942). Such specific differences in the temperature tolerances of fish and of other poikilothermal animals may explain differences in their geographical distributions and breeding ranges (Orton, 1920 ; Runnstrom, 1927). There have not been many precise experiments, however, on the tolerances of eggs and larvae. These are likely to be more sensitive to extreme conditions than the adults are. Conclusions of great ecological significance are likely to emerge from experiments dealing with the temperature tolerances of fish. It is also of importance to have the knowledge of the optimum conditions of temperature, if a species is to be kept safely in the laboratory.

The experiments on which the following conclusions are based dealt mostly with the survival time of the larvae kept at constant temperatures. Equal numbers of larvae were kept in jars, each of which was provided with a thermostatically controlled heating arrangement. For maintaining constant temperatures below 10°C, some such jars were kept in a culture cabinet, running at 0-1°C, which had a large glass window. All jars had similar natural illumination. The jars were supplied with *Artemia* nauplii and kept well aerated by bubbling compressed air. Before

the larvae were transferred into various jars, each jar was filled with fresh sea water at the exact temperature at which the larvae were originally kept. After the transfer of the larvae, the refrigeration and heating in all the jars were switched on. The larvae in this way were subjected to changes in temperature which were only gradual and which took between 12 to 16 hours to reach the levels desired for the experiment. When these levels had been reached, the experiment was considered to have begun. The larvae which died were removed twice a day and their total numbers from each jar were counted after every 24 hours.

The percentages of larvae of *C. gunnellus* surviving at various temperatures during the first seven days of an experiment are given in Table I. On the eighth day practically all the fish died, probably because of a cut in electric power and refrigeration failure, so this experiment had to be discontinued. Differences in survival rates between the various batches had already become clear however. Both 15° and 20°C eventually proved lethal to this species. The optimum temperature seemed to be about 5°C. At lower temperatures it is not certain that the larvae were very adversely affected. Even at 0-1°C practically all remained healthy for the first few days, but later some began to show signs of inactivity and considerable numbers died. This mortality, however, may well have been due to starvation, as these low temperatures were beyond the tolerance limit of the *Artemia* nauplii which were given as food.

TABLE I

Percentage of larvae of *C. gunnellus* surviving at the end of each day, when kept at various constant temperatures. (The experiment was unfortunately terminated after 7 days.)

Number of days.	TEMPERATURES					
	0-1° C	3° C	5° C	10° C	15° C	20° C
1	98	96	100	100	92	90
2	96	94	96	94	82	50
3	80	88	96	92	40	8
4	78	84	94	88	10	0
5	74	80	92	88	5	
6	72	76	90	86	0	
7	70	76	86	84		

A similar experiment with larvae of *B. Pholis* was carried through to completion without accident, but pressure of other work did not allow a complete record of the daily mortality at each temperature to be maintained. The results of this experiment are therefore shown in Table II as the maximum survival times at the various temperatures. It will be seen that all low temperatures up to 5°C were rapidly lethal (Table II). The larvae showed signs of distress as soon as or even before the required temperatures were reached and all larvae kept at 0°, 2° and 5°C died within 48 to 72 hours. At the lethal high temperature (30°C), there was no sign of shock at first. Some larvae began feeding at this temperature and continued to do so until they started dying in multitudes, their maximum survival time being 4 days.

TABLE II

Maximum survival time of the larvae of *B. pholis* at each constant temperature.

Temp.	0-1° C	2° C	2° C	5° C	23-25° C	30° C
Survival in days.	2	2	3	36	25	4

Similar experiments were made on embryos of *C. gunnellus*. Egg masses, with embryos clearly visible to the naked eye, were collected early in the breeding season. Each mass was then carefully broken into several portions and the portions from each mass were distributed between various constant-temperature jars. Within a few days after the commencement of the experiment, it became evident that the eggs kept at 15° and 20°C were turning opaque, and after 10-15 days most of the eggs at these temperatures were dead. On examining under a microscope, the dead eggs were found to be attacked by fungus. At temperatures 0-1°, 3°, 5° and 10°C, the eggs remained healthy for about 20 days, but eventually all died because of fungal infection. Under such conditions, it is difficult to say whether temperature alone was responsible for causing an early mortality at 15° and 20°C. It is of course possible that growth of fungus was encouraged more at higher temperatures than at low temperatures. Embryos of *C. gunnellus* proved to be able to withstand freezing, for an egg mass was kept in a deep freeze cabinet until it was frozen solid. On thawing, the embryos were found to be healthy and showing their characteristic movement inside the egg capsule. Other authors have shown that adult fish of some species are capable of surviving, after being frozen solid for a long time (Borodin, 1934).

These studies, therefore, show that the larvae and possibly the embryos of *C. gunnellus* are extremely intolerant of higher temperatures, but are resistant to low temperatures. Larvae of *B. pholis*, on the other hand, are intolerant of low temperatures, but can withstand comparatively high temperatures. These differences are associated with differences in the geographical distribution and breeding habits of the two species. *C. gunnellus* is an Arctic species which in European waters reaches its southern limits in the English Channel. Since its eggs and larvae require low temperatures, the fish breeds during the coldest time of the year (January-March). This short breeding season, occurring at the same time throughout the geographical range, is probably an adaptation which enables the larvae to take advantage of the short Arctic season of plankton production (Qasim, 1956a, 1957b). *B. pholis*, on the other hand, being a southern species (Mediterranean-boreal), breeds over a prolonged period during spring and summer (Qasim, 1956b, 1957a). Its larvae are not exposed, therefore, to the low temperatures which they cannot tolerate.

GAS DISEASE

It was often noticed that some of the larvae of *B. pholis* developed ' gas disease ' and died. The larvae showed symptoms similar to those described earlier in the young cod (Henly, 1952). They became buoyant, and though they made repeated attempts to swim down, they generally remained for the most part floating near the surface until they died, generally a day or two after the onset of the condition. On examination, their swim bladders were found to be unusually enlarged, apparently as a result of excessive gas secretion. Cases of gas disease were not very frequent, but occurred in most of the jars, and generally started when the fish were almost

one month old. The majority of larvae which died showed no sign of gas disease, but gradually turned pale.

The larvae of *C. gunnellus*, which lack swim bladders, showed no sign of gas disease. Larvae which died developed opaque spots, generally appearing first in the posterior region of the body, and soon spreading all over it. Such larvae, when examined, showed no gas bubbles either externally or internally.

It seemed likely that the gas disease of *B. pholis* was due to malfunctioning of the gas gland associated with the swim bladder, but it is uncertain whether the freedom from gas disease in *C. gunnellus* was due to the absence of these organs or whether it was due to the lower temperatures prevailing in the season during which the larvae were reared. The warmer weather later in the summer, when *B. pholis* were being reared, may well have caused the water, drawn from the cooler sea, to be supersaturated with gases.

Summary

The survival rates of larvae of *Blennius pholis* and *Centronotus gunnellus* have been studied in the laboratory, under different experimental conditions. Survival of larvae in jars containing *Chlamydomonas* and *Isochrysis* was slightly better than in jars without any food. The flagellates, however, seemed of very little food value, prolonging life only for two or three days. Larvae fed on flagellates together with *Artemia* nauplii survived no better than larvae fed on nauplii alone.

Larvae under alternate periods of light and darkness became more active, grew more quickly and survived longer than those kept under continuous illumination. The moderate agitation of the water caused by an unconfined stream of air bubbles was shown to have a beneficial effect on growth and survival and was found to be preferable to the use of plungers. A small proportion of the larvae of both species were reared until fully metamorphosed.

When kept at constant low or high temperatures, larvae of *C. gunnellus* (an arctic-boreal species) withstood 0° to 10°C, but soon died at 15° and 20°C. Larvae of *B. pholis* (a mediterranean-boreal species) were killed at 0° to 5°C, survived at higher temperatures of up to 25°, but soon died at 30°C.

Some larvae of *B. pholis* died of gas disease, their swim bladders being greatly distended. No cases of gas disease were seen in *C. gunnellus*, a species which lacks a swim bladder.

Acknowledgements

I am most grateful to Dr. D. J. Crisp, Director, Marine Biology Station, University College of North Wales, Bangor, and Professor E. W. Knight-Jones, Department of Zoology, University College of Swansea, U.K., for their advice and critical reading of this manuscript.

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SOME ASPECTS OF MARINE MICROBIOLOGY

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Introduction

Marine sediments have been studied by geologists and palaeontologists and the benthos, particularly bacteria and animals, have received attention from bacteriologists and biologists. There has, however, been insufficient examination of the sea bottom, its fauna and flora, as a part of the marine biological system. The studies made give no clear indication of the extent of the interaction between the bottom and the sea itself.

Microbiology of Marine Muds

Wood (1956) showed that the bottom muds collected from the ocean deeps by the Danish research ship *GALATHEA* included diatoms, some of which still contained protoplasm. Moreover, these diatoms were benthic species, and no planktonic forms were observed in any of the samples. All of the species found in the *GALATHEA* material except *Ethmodiscus rex* have also been collected from estuaries of Australia and New Zealand (*see* Crosby and Wood, 1959 ; and Wood MS.).

More recently a study has been made of the sea bottom on the continental shelf east of Port Hacking, Australia, at depths from 60 to 120 metres. Samples taken weekly over six months invariably showed pennate diatoms with a few benthic discoid species. The diatoms contained chloroplasts and many of the pennate forms e.g. *Navicula* spp., *Pleurosigma* spp. were actively motile, although the one per cent. surface illumination level did not exceed 87 metres in 33 observations made in 1955-7 by Jitts (1959), i.e. the diatoms were in many cases below the theoretical euphotic zone. Cultures in Allen and Nelson's medium (Allen and Nelson, 1910) yielded growths of *Navicula*, *Nitzschia*, and *Pleurosigma* species. Table I gives a list of the diatoms found in the various benthic environments for comparison.

It will be seen that there is a continuity between the estuarine bottom flora through the continental shelf flora to that of the ocean deeps, and this would appear to confirm Wood's (1956) suggestions that these benthic floras are ecologically related to each other, and that they constitute a separate and distinctive biocoenosis. The diatoms of the estuarine muds are reinforced by epontic species which fall on to the muds and are included in the mud flora. This, and the large number of samples may account in part for the comparative diversity of the estuarine flora, but it is probable that the number of species in the plant communities diminishes seaward. Although the studies on the bacteria of marine sediments in deeper waters are few, the evidence suggests that the bacterial flora in such places does not differ materially,

TABLE I

Diatoms of the Estuarine Muds, Continental Shelf and Ocean Deeps*

Estuaries near Sydney	*Shelf*	*Deeps*
Synedra fulgens	Synedra sp.	Synedra tenera
S. frauenfeldii	Grammatophora marina	Navicula
S. ulna	Achnanthes brevipes	Cocconeis pediculus
Grammatophora marina	Achnanthes dispar	Pinnularia dactylis
Licmophora abbreviata	Cocconeis placentula	Trachyneis aspera
L. grandis v. divisa	Navicula hennedyi	Pleurosigma normanii
L. flabellata	N. lyra	Diploneis crabro
Terpsinoe musica	N. lyra v. australica	Nitzschia panduriformis
Striatella unipunctata	N. gracilis	Melosira granulata
Achnanthes longipes	N. brasiliensis	M. moniliformis
A. brevipes	N. luxuriosa	Coscinodiscus centralis
Cocconeis heteroidea	N. sulcifera	C. marginatus
Cocconeis placentula	Diploneis crabro	C. pacificus
C. scutellum	Trachyneis aspera	Ethmodiscus rex (fragments)
Navicula subcarinata	Diploneis smithii	
N. cyprinus	D. fusca	
N. granulata	D. finnica	
N. brasiliensis	D. rostrata	
N. lyra	D. pseudobombiformis	
N. yarrensis	Amphora graeffii	
N. grevillei	A. proteus	
N. lyra	A. bigibba	
N. lyra v. elliptica	A. cuneata	
N. lyra v. australica	A. weissflogii	
N. peregrina	Pleurosigma balticum	
N. radiosa	P. angulatum	
N. spectabilis	Amphiprora alata	
Neidium affine	Nitzschia distans	
N. amphigomphus	Campyloneis grevillei	
N. iridis	Campylodiscus biangulatus	
Trachyneis aspera	Mastogloia lineata	
Pinnularia major	Skeletonema costatum (spores)	
P. brevicostata	Melosira sulcata	
P. gibba	Hyalodiscus stelliger	
P. splendida	Pyxidicula cruciata	
P. stauroptera	Coscinodiscus nitidus	
Diploneis crabro	Coscinosira sp.	
D. fusca	Triceratium sp.	
D. chersonensis		
Dictyoneis marginata		
Pleurosigma angulatum		
Pl. balticum		
Pl. formosum		
Anomoeoneis serians		
A. sphaerophora		
Mastogloia cribrosa		
M. quinquecostata		
M. gracilis		
M. smithii		
M. rostellata		
Tropidoneis lepidoptera		

* Port Hacking, Botany Bay, Lake Macquarie, New South Wales

TABLE I—(*Contd.*)

Estuaries near Sydney	*Shelf*	*Deeps*
Amphora robusta		
A. hyalina		
A. proteus		
A. lineolata		
A. ostrearia		
A. gigantea		
A. rhombica		
A. javanica		
A. arcta		
Epithemia argus		
Campylodiscus ornatus		
C. adriaticus		
C. undulatus		
Melosira moniliforme		
M. sulcata		
M. nummuloides		
M. granulata		
M. juergensii		
Coscinodiscus marginatus		
C. pacificus		
C. radiatus		
C. argus		
Actinoptychus senarius		
Aulacodiscus margaritaceus		
Auliscus sculptus		
Biddulphia pulchella		
B. aurita		
Triceratium favus		
T. robertsianum		
T. alternans		
Isthmia nervosa		

except in relation to hydrostatic pressure, from that of the continental shelf and of estuaries (see Waksman *et al*, 1933 ; Zobell, 1946, 1952 ; Wood, 1953 ; Kriss and Rukina, 1953 ; Baas Becking and Wood, 1955).

The Relation Between the Benthic Flora and that of the Neritic Plankton

In addition to the benthic diatoms of the continental shelf bottom, spores of planktonic forms may occur. Thus, on one occasion, in August, just prior to the spring maximum, a culture from the continental shelf mud at 120 metres yielded a unialgal culture of the planktonic diatom *Skeletonema costatum*, of which the spores had been previously observed in the mud. It is interesting to note that, a week later, the surface water samples from the same station yielded a bloom of this diatom, while an old culture of *S. costatum* which had become overgrown by *Navicula grevillei*, when subcultured on the same date as the mud sample was collected, gave an apparently unialgal culture of *S. costatum*. The question arises, does this suggest a biological rhythm in phytoplankton. Diurnal, tidal rhythms have been demonstrated in diatoms by Callame and Debuyer (1954), and a lunar rhythm for *Goniaulax* has been suggested by Sommer *et al.* (1937) and Wood (1954).

Further evidence in this connection is given in Figure 1. In this experiment a sample of sea water from the laboratory pond was placed in glass and plastic jars in the laboratory, one of each in the daylight, one under artificial light, and one in the dark at room temperature. Direct counts of the diatoms in the jars and in the pond

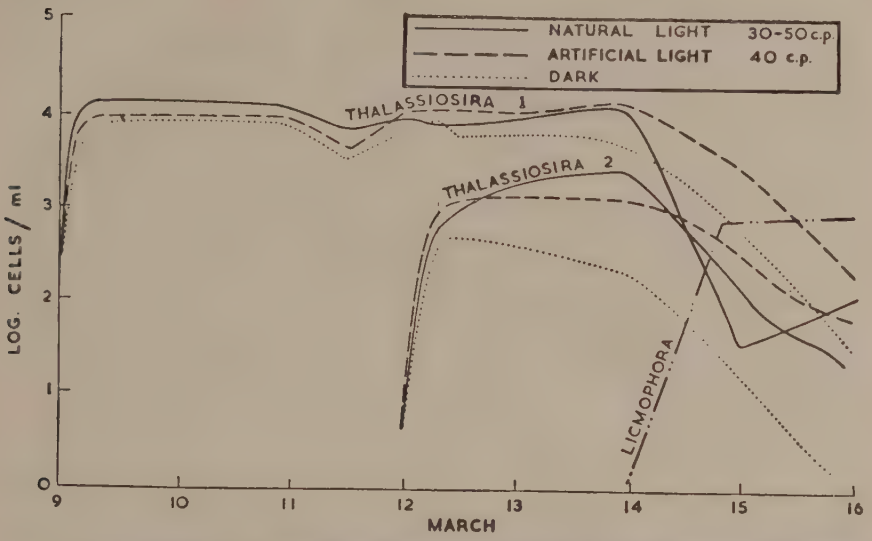

FIG. 1. Growth curves for diatoms expressed as log. cells/ml. in sea water samples in natural light, in artificial light, and in darkness. Series 1 represents the original, series 2 the later isolation.

were made at regular intervals and the growth of the predominant diatom *Thalassiosira aestivalis* plotted as Log_{10} cells. There was no significant difference in the growth rates in plastic and glass bottles, and only a relatively slight decrease in the growth rate in the darkened bottles.

The count of *T. aestivalis* in the pond remained approximately constant between 400 and 500 cells per ml. In the jars however, there was an immediate and very rapid logarithmic increase for the first four hours, after which the rate tapered off to the stationary phase which lasted for over four days and was followed by the death phase. It is interesting to note that natural light gave slightly better growth than artificial light of the same candle power, while the darkened bottles multiplied slightly more slowly and did not reach quite the same maximum population. When *Thalassiosira* was declining, *Licmophora abbreviata* grew logarithmically for ten hours.

A second isolation of *T. aestivalis* made from the pond on the third day increased logarithmically, but to a lower population level, and entered the death phase at the same time as the original culture. Samples taken from the pond after the fifth day failed to grow. These facts suggest a rhythm, but whether due to external or internal factors is not known.

The appearance of *Skeletonema costatum* in the surface water off Jibbon Cape following the appearance of the species in culture is open to two interpretations: 1. the diatom emerged from the spores *in situ* and floated to the surface, or 2. there was a turnover and mixing of the mud and water, the bloom actually occurring at the surface.

Further studies on the muds and surface waters gave evidence on this. The Eh of the surface muds over the six month period was + 170 mV, ranging from + 50 to + 250 mV at an average pH of 7.0 (6.6 to 7.4). During this time, on three occasions, the sulphate reducing bacterium *Desulphovibrio desulphuricans* was isolated from the surface water (Eh + 430 mV), and on two of these occasions a Chlorobium and a Chromatium (two photosynthetic sulphur oxidizing bacteria) were isolated. All these bacteria are strict anaerobes, and grow only at Eh values far below that of the water or most of the surface muds (see Baas Becking and Wood, 1955). These organisms could only have been derived from the bottom in a region where the Eh value was below + 110 mV for active *Desulphovibrio* and below —110 mV for the Chlorobium, though these organisms can exist but not assimilate at higher Eh values.

Putting the facts together, we may conclude that vertical mixing of surface muds and the waters of the continental shelf is responsible in part for the neritic blooms of phytoplankton, and possibly contributes nutrients as well as microorganism. We know (Baas Becking and Macay, 1956) that sulphate reduction can cause release of phosphate in the muds, while nitrogen fixation by many anaerobes has been established.

I was somewhat surprised at the high Eh values of the surface of the muds at the Port Hacking stations, but this would account for the fact that I failed to find many true (as distinct from facultative) anaerobes in this region on the continental shelf. Prevot (1958) has criticised my technique (Wood, 1953) on account of the findings of Callame (1951). However, Callame's samples were taken in lagoons and estuaries with a considerable amount of pollution where one would expect low Eh values and a correspondingly increased possibility of true anaerobes occurring. One would not expect true anaerobes, except adventitiously, at Eh values of + 100 mV or more.

Photosynthetic Microorganisms Below the Photic Zone

One other point arising from the observations here recorded is the repeated finding of photosynthetic microorganisms at depths below the euphotic zone. These include diatoms, flagellates and photosynthetic bacteria. For instance Bernard (1942) recorded coccolithophores at 4,000 metres and Kriss and Rukina (1953) recorded active photosynthetic sulphur bacteria at depths of 2,500 metres in the Black Sea. The Russians gave experimental evidence that the purple and green sulphur bacteria were actively photosynthetic *in situ*, and as there was no light at such depths, they suggested that the bacteria were using radioactive energy. While I find this explanation hard to accept, I have no alternative to offer. Another possibility for the growth of photosynthetic microbes below the photic zone is that they are growing heterotrophically. We know (Lewin, 1953, and Wood, 1956) that some diatoms are capable of heterotrophic growth, even at pressures up to 500 atmospheres, but Kriss and Rukina gave good evidence that their photosynthetic bacteria were

incapable of heterotrophic growth. Because of the number of records of photosynthetic microorganisms occurring in quantity below the photic zone, we cannot assume that the organisms are inert or are living a heterotrophic existence. Perhaps the organisms below the euphotic zone are in the stationery or death phases of their growth curves, perhaps those autotrophic microbes which are found below the compensation point as normally determined have lower light requirements or a lower katabolic rate than others, or perhaps they are using sources of energy other than sunlight for the reduction of carbon dioxide.

The observations and experiments recorded in this paper pose more problems than they solve. They are given in order to stimulate thought, and to warn against over simplification of problems in marine microbiology.

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ON UPWELLING AND BOTTOM-TRAWLING OFF THE SOUTHWEST COAST OF INDIA

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Introduction

While starting an investigation on basic production off Cochin at the southwest coast of India, a section across the shelf with serial observations on temperature, salinity, and oxygen content was run in the last week of August 1958. The bottom water was observed to be very badly aerated, and from the hydrographic data it was inferred that these conditions were connected with upwelling. Berner and Schemainda (1957) have shown for the basins of the Baltic that at low oxygen figures the cod either migrates away or turns to midwater life so that bottom trawling becomes unprofitable. Therefore, it was thought worthwhile to investigate closely the upwelling and its effect on the catch of demersal fishes off Cochin.

Extent of Upwelling

Upwelling off Cochin and farther south was found by Sastry and Myrland (unpublished) during their first series of cruises in October 1957. The phenomenon extended to a mean distance of 60 miles from the shore, and it was stated that the upwelling water reaching the surface came from depths between 50 and 75 m. The duration of upwelling and its extent towards north were not determined by the authors.

From previous investigations the following can be concluded : As shown by Sewell (1929) there is a double seasonal oscillation of the surface temperature of the water in the Laccadive Sea which is connected with the monsoons : Maxima of surface temperature are observed before and after the SW-monsoon whereas during the SW-monsoon season the temperatures are low. The effect of the summer monsoon on the surface temperature is distinctly shown by the investigations on the yearly variation of the temperature and evaporation from tanks near Trivandrum (Broune, 1906). But whereas Sewell estimated the yearly variation of monthly average temperatures in the Laccadive Sea to be 1.88°C (2.7° in the tanks of Broune), the variation in the surface data of the sea near Calicut is 4-5°C ; for the surface waters of this area, observations are published for a period of 16 years (Chidambaram, 1950 ; George, 1953 ; Seshappa and Jayaraman, 1956 ; Kasturirangan, 1957) which show that after the annual maximum of the inshore water temperature in April/May of about 30°C, there is a sudden decrease in June ; in some years the monthly average temperature begins to decrease in May. The lowest averages of about 25°C are found in July/August, and only in October/November is a remarkable increase of the monthly average temperature usually noticed (secondary annual maximum of about 29°C). So the annual minimum of surface temperature in the sea off Calicut is found during summer time.

The data collected by George (1953) from 1949 to 1952, given as weekly averages, show that the fall in surface temperature during May/June occurs suddenly. It is not related to the onset of the monsoon rain. Further, the observations made by Seshappa and Jayaraman (1956), at 19 m depth, as well as those of Sastry and Myrland (MS), demonstrate that at this depth, the temperature before SW-monsoon is nearly as high as that at the surface. So the sudden decrease of the surface temperature during the onset of the monsoon is not caused by turbulence due to the increased wave action either, but is due to upwelling. The larger variation of monthly average surface temperature off Calicut during 16 years of observation, compared with that of the open Laccadive Sea indicates that off Calicut upwelling is regularly

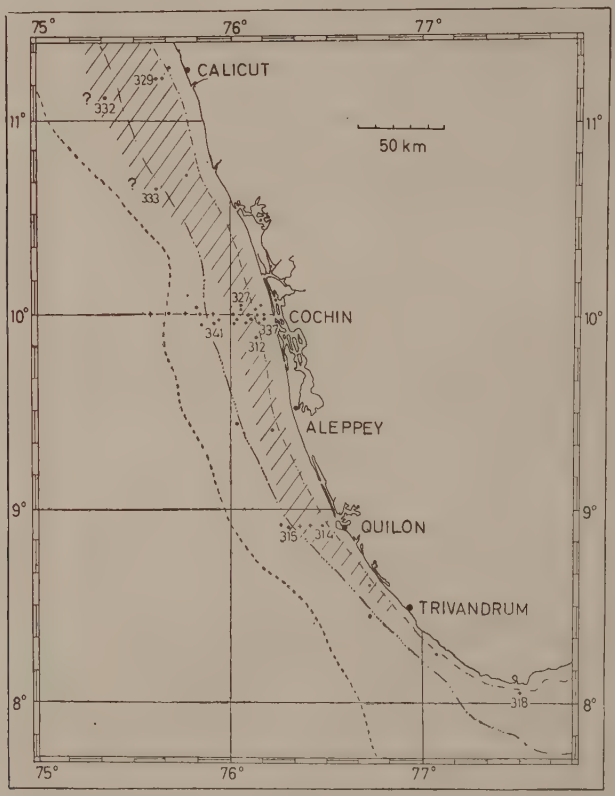

FIG. 1. Area of investigation. Of depth contours, the 20m, 50m and 180m (100 fs isobaths are given. '.': Station with serial observations, eventually with bathythermograph reading. '+': Station with bathythermograph reading only. Off Cochin, all stations were done on 9° 58′ N, except from nos. 312 and 327. The hatched area indicates the region where during the visits in September/October 1958, according to oxygen observations, bottom trawling would have been unprofitable.

found during the whole period of SW-monsoon ; its effect is felt strongest in July and August (refer also to the observations on phosphate content off that place, p. 35), and it lasts till October. The proof for the deduction that upwelling is the reason for the peculiar temperature conditions near Calicut, is the rise of temperature towards the open sea (Horizontal gradients in October 1957 of 1°C per 15 m, as stated by Sastry and Myrland), as well as the vertical distribution of temperature observed in 1957 and 1958 (Fig. 3).

According to the observations in 1957 and 1958, the upwelling extends southwards to Cape Comorin (*i.e.* to 8° N, Fig. 2). Towards north the upwelling certainly reaches 15°, and perhaps 18° N., as shown by the following discussion.

The observations compiled in ' Temperatuurmaandkaarten vor de Indische Oceaan ' (Anon., 1952) show cold water off the southwest coast of India to occur from June to August and even October (extending to about 15° N, *i.e.* south of Goa). According to the ' World Atlas of Sea Surface Temperatures ' (Anon., 1948), and the ' Monthly Meteorological Charts of the Indian Ocean ' (Anon., 1944-45) cold water is found off the Indian southwest coast in August and September. The inconsistency of the temperature distribution, as given in these publications which are mainly based on the regular observations of merchant vessels, is understood by the fact that the bulk of the data is collected along the tracks of traffic ; due to the restricted harbour facilities along the west coast of India during SW-monsoon, observations from the area near the coast are to be expected only from a small number of places. Interestingly enough, the calculation of the range of sea surface temperature in the respective months which is based on the same material (' Monthly Meteorological Charts of the Indian Ocean '), seems to show the occurrence of upwelling more clearly than the charts of mean or minimum temperatures. It appears that off the south west coast, in varying extension, an area is found with a range of $>6°$ F (*ca.* 3.3°C). It is smallest in June (*i.e.* the surface temperature is invariably low as shown by the chart of the mean temperature ; upwelling occurs most regularly), and extends to 16-17° N in September/October. Towards south, the Gulf of Mannar and the southern coasts of Ceylon generally are included in the area with a range $>6°$ F ; also the mean temperatures south of Cape Comorin (Wadge Bank) are low so that the upwelling extends mostly or always to the area of the continental slope.

The observations of Jayaraman and Gogate (1957), on the shelf off Bombay, indicate a decrease in surface temperature during this season that mostly is stronger than to be expected from the temperature variation of the Laccadive Sea as computed by Sewell (1929) ; if it would be caused by the monsoon wind effect on the evaporation alone, it could hardly become so large. Apparently, off Bombay, the fall of temperature sets in during August only, and is not so marked as off the southwest coast, as far as it can be derived from the regional averages given by the authors.

The analyses of total phosphorus content of surface water by Jayaraman and Seshappa (1957) reveal that during SW-monsoon, as far north as the observations were extended (18° N), the surface figures in this season are consistently higher than during NE-monsoon. Also this fact indicates that upwelling in some form occurs so far to the north. For detailed discussion of phosphate distribution see p. 41.

In order to illustrate the actual temperature distribution during the upwelling period, a section parallel to the southwest coast run by R.V. KALAVA along the 25m contour line in September/October 1958 is given in Fig. 2*a* (Inner line of stations in Fig. 1). The salient features are the low surface temperature south of Alleppey (Station 313) and the very shallow thermocline north of that place ; only south of Alleppey the upwelling water reached the surface so that the surface values of temperatures (and of oxygen, Fig. 2*b*) were considerably lowered.

The observations were made after the time, when usually the annual minimum surface temperature is to be found. The sections north and south of Cochin were not run simultaneously, as indicated in the top of Fig. 2*a*, but measurements off Cochin prove that—at least there, and leaving apart the influence of the back-waters above 10 m depth which depends on the state of the tide—the conditions did not change too much during the interval. During September, at about 50 m depth the thermocline sank down hardly 10 m which suggested some weakening of the forces causing the upwelling. The high surface values of temperature off Cochin (Station 312 and 327 in Fig. 2*a*, 27° C) were accompanied by low salinities ; this place is very often influenced by the land-locked back-waters. The lowering of isotherms off Quilon (Station 314) was a local disturbance that was not related to the state of the tide. Off this station, a 9-mile section was run across the shelf which revealed the sinking of isotherms to be restricted to the area near the coast.

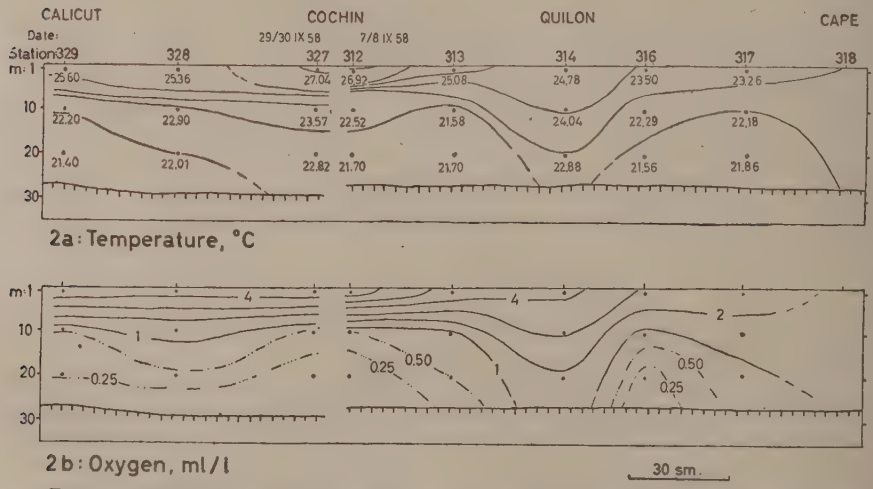

FIG. 2. Section of temperature and oxygen content along the southwest coast of India. The depths of isotherms are based on bathythermograph readings ; the readings from reversing thermometers are entered for purpose of comparison.

The same conditions as shown in Fig. 2*a* hold good off Calicut also for previous years. Apparently, the upwelling water there reaches the very surface only occasionally as indicated by sudden drops of temperature (see the weekly averaged observations of George, 1953). Then, also off Calicut, the surface temperatures may

register a fall to 23.2°C, as shown by the values of extreme temperatures for 1950 (Seshappa, 1953). This lowers the average surface temperature far enough to become visible in monthly charts as discussed earlier. A section along the 55 m contour line at about the same time as that of Fig. 2 (Outer line of stations in Fig. 1) fundamentally gave the same results as that for the near-shore waters. Generally, the thermocline was found between 10 and 20 m depths ; it tended to widen slightly.

The upwelling along the west coast of India may be caused by the following events : According to the ' West Coast of India Pilot ' (Anon., 1950) towards the end of the NE-monsoon season, the current off the west coast turns to SE (end of February to April). After the onset of the SW-monsoon the coastal current becomes considerably stronger, and, consequently, on its left side the more dense deep water must rise ; supposing a uniform current velocity all along the coast, the rise will be stronger in the north, farther away from the Equator. By this, cold water will enter the shallower parts of the shelf along the entire west coast, and it might depend on the wind when this water will reach the surface (' Upwelling ' in the strict meaning of the term). In the same way, Schott (1935) has explained the occurrence, during SW-monsoon, of cool water off the south coast of Ceylon. This upwelling area appears to be continuous with that off the south-west coast of India as can be seen from ' Temperatuurmaandkaarten vor de Indische Oceaan ' quoted earlier. According to the ' Monthly Meteorological Charts of the Indian Ocean ' (Anon., 1944-45) the predominant winds, as well as the resultant winds (vector means) exhibit under the first half of the SW-monsoon, off the southwest coast of India, a more marked western component than off Bombay. This difference continues also later when directions from W to NW are prevailing in the monsoon wind (August/September). In consequence, the water transport by the wind driven current always gets a stronger off shore component off the southwest coast than off Bombay ; and for the latter region it is seen that upwelling due to wind action normally will occur only from August onwards, as indicated by the observations published by Jayaraman and Gogate (1957).

During the SW-monsoon season, Trivandrum receives winds from W or NW much more regularly than Cochin (' Climatological Tables of Observatories in India ', Anon., 1953). Further, as already pointed out by Sastry and Myrland (unpublished) the coast line south of Quilon bends SE so that the offshore component of the wind driven current is increased. Finally, some divergence in the coastal current may be caused by the fact that the shallower parts of the shelf in that area become narrower so that the near-shore current bends away from the coast. Therefore, both in 1957 and 1958 in the second half of the SW-monsoon season (earlier observations are not at hand), continuous presence of cold water at the surface was found south of Alleppey and Quilon (See Fig. 2 *a*, stations 313 and 314).

Certainly, the prevailing current system, and not the wind, is to be regarded as the main reason for the upwelling off the southwest coast of India as indicated by the following consideration : Both by its geographical position and by its large north-south extent this upwelling area bears some resemblance to the ' classical ' upwelling regions off the west coasts of the continents in low latitudes, *i.e.* at the eastern sides of the trade wind regions. However, the upwelling in the area in question does not occur when the air circulation is similar to that of the trade wind system, *i.e.* during

NE-monsoon, but during SW-monsoon. This explains the climatological difference against other upwelling regions. Whereas elsewhere during upwelling fog frequently is met with, off the south west coast of India during this season heavy precipitation is observed which causes stabilisation of the coastal waters by lowering of salinity.

It should be noted that, according to Sastry and Myrland, in depths below 75 (50) m the current runs north. This feature is found in many other upwelling areas also (Yoshida and Mao, 1957 ; earlier literature is quoted there).—As another example of upwelling off the coasts of India, from the Bay of Bengal, the paper of La Fond (1957, with figures of oxygen and nutrient salts distribution) may be referred to ; upwelling there occurred in spring during SW winds.

Effect of Upwelling on the Distribution of Oxygen and Nutrient Salts

As in the case of the temperature, the distribution of oxygen, pH, and nutrient salts during SW-monsoon is decisively influenced by the upwelling. From the observations off Calicut by earlier workers it appears that near the coast the effect of upwelling is felt most from July to September.

Observations on the oxygen content of surface water near Calicut is available for a period of six years (*vide* Kasturirangan, 1957 ; and Subrahmanyan, 1958). In the six years' averages of Subrahmanyan, the minimum of about 3.5 ml/L O_2 (*ca.* 72% of the saturation value) is observed in September, the maximum of about 5.0 ml/L (*ca.* 108%) in November. During the peak of the phytoplankton standing crop in July (Subrahmanyan), the average value of about 4.35 ml/L (*ca.* 87%) is very small especially for stratified waters as they prevail during this season. Taking the conditions during individual years of that period into consideration (*vide* Kasturirangan, 1957), it is seen that the minimum always occurs is September (the lowest average is 3.01 ml/L O_2, *i.e.* 58.5% of the saturation value, based on 8 observations) whereas the trend during the preceding months varies considerably. The highest average saturation of 125% during four years of inshore observations was found in July 1950, not in November as in the six years' average of Subramanyan. Generally speaking, it is seen that the high stock of phytoplankton found during SW-monsoon is not producing enough oxygen to lift the content up to the saturation level.

For four years, from about the same place of observations as in the oxygen sampling, measurements of pH are at hand[1] : The surface water in 1949/50 and 1951-53, and in 1952/53 the bottom water from 4 and 19 m depths, exhibited rather low figures from June (May) to September. The minimum of 7.6 in the bottom water of September, at the inshore station of Seshappa and Jayaraman (1953), which is 0.3 units lower than the figure of the underlying mud at that time, indicates that the decrease of pH during monsoon time cannot be caused by the stirring up of the sediment and by the release of the interstitial water alone. But both the oxygen and pH

[1] 'Administr. Rep. Dept. Fish. Madras, for 1951/52 (Anon., 1952) ; observations published in older reports were not available to me. Seshappa (1953) ; Seshappa and Jayaraman (1956) ; ' Fisheries Stations Reports and Yearbook, Dept. Fish. Madras, for 1954/55 ' (Anon., 1956).

figures are heavily affected by the upwelling which brings badly aerated water to the surface.

An example of the oxygen distribution met with during the present investigation is given in Fig. 2 *b*. The picture resembles that of the temperature distribution (Fig. 2 *a*) ; stronger vertical mixing is observed at Quilon (Stations 314/315) and farther south by which the oxygen values at 1 m depth are lowered to nearly 50% of the saturation value, whereas the bottom figures are higher than in the north. North of Quilon, the oxygen content 5 m above sea-bed is very low (as long as the observations lasted, off Cochin $\leqslant$0.5 ml/L O_2, *i.e.* $\leqslant$10% of the saturation value was found ; off Calicut, 30, IX. '58 to 2.X. '58$\leqslant$0.2 ml/L *i.e.*$\leqslant$4% saturation was observed). In the offshore section mentioned above, along the 55 m contour line, the trend was similar. The surface values varied between 4.1 and 6.9 ml/L O_2 (86 and 141% of the saturation value) ; near the sea-bed south of Quilon $>$ 1 ml/L O_2 was found, off Cochin 0.65 ml/L, and off Calicut O ml/L ($>$ 20, 12 and 0% of the saturation value resp.). Also at station 333, situated 33 miles south of station 332 (see Fig. 1) no oxygen was observed 5m above sea-bed. Off Cochin repeated observations are at hand which show that the seaward extension of the area with 0.5 ml/L O_2 (less than about 10% of the saturation value) varied considerably : On five occasions between the end of August and the beginning of October, 1958, in the sample above the sea-bed, this figure was found at depths varying between 38 and about 80 m *i.e.* between 15 and 30 miles from the shore. The figure of 0.25 ml/L (about 5% of the saturation values) was found on the same occasions at depths between 20 and 41 m.

Fig. 3 demonstrates these conditions during a section across the shallower parts of the shelf off Cochin on Oct. 7, 1958. It appears that the water highly depleted of oxygen is confined to the vicinity of the bottom, *i.e.* that the oxygen consumption near the sea-bed is very high. The oxygen content can become so small because the original concentration in the upwelling water is low. The temperature indicates that the water is coming from the layers just below the thermocline, *i.e.* from above the depth where the upper intermediate oxygen minimum of the tropical oceans is found (see Sastry and Myrland about the depth from where the rising water originated in 1957). The observations of the ' Dana '-Expedition (Thomson, 1937) and the Swedish Deep-Sea Expedition (Bruneau, Jerlov and Koczy, 1953), as well as investigations made by the present author off Cochin in November/December 1958, prove that in the south and southwest of India, north of the Equator, the oxygen content of water at about 20°C is often as low as 1 ml/L (roughly 20% of the saturation value) though somewhat higher figures do occur also. Because the oxygen content of the coldest water ($<$21.5° C) met with on the inner shelf off Cochin (upto 100 m depth) during the upwelling period of 1958, was 0.65—0.70 ml/L, the higher consumption does not start on the shallower parts of the shelf only, as it may be derived from Fig. 3 *b* ; but only on the shallower parts of the shelf the oxygen depletion turns critical for the demersal fishes as discussed later.

According to the observations of the John Murray Expedition (Gilson, 1937), in the Arabian Sea off the coasts of India, the thermocline and the intermediate oxygen minimum layer are rising towards north to shallower depths ; this is accompanied by the lowering of the oxygen concentration in the minimum layer. The observations were made in autumn and winter time ; but if the results

are true for the season of the summer monsoon also, upwelling even from shallower depths than observed off the southwest coast, off Bombay can cause as bad conditions as off Cochin. On p. 37 it was mentioned that due to the coastal current,

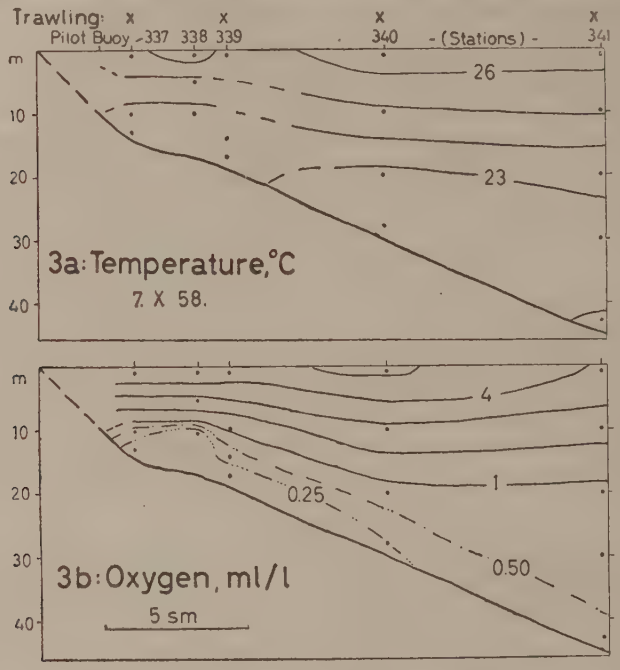

FIG. 3. Temperature and oxygen distribution off Cochin on Oct. 7, 1958. ' × ' marks stations where exploratory trawling was performed.

all along the west coast of India, the shallower parts of the shelf will be entered by the cool deep water during southwest monsoon. Even if off Bombay this water is not reaching the surface so that the average temperature is brought down, it may happen that at rather shallow depths (about 50 m) biological conditions prevail which are similar to those that are the rule off Cochin during this season.

The belt of heavy oxygen-depletion running along the Malabar Coast will not touch the very shore as shown in Fig. 3 *b* ; this is due to the vertical mixing caused by the wave action on small depths which effects a steady stream of oxygen from the surface down. The outer border of the aerated inshore zone at a certain place depends on the strength of the wave action, and should be found farther out during the first monsoon months. Off Cochin, at the time of the present investigation (August to October) usually it occurred within the 10 m contour, for, near the coast the oxygen values at 10 m depth were mostly very low.

Before concluding the discussion of the oxygen distribution, a remark on the phytoplankton cycle during the upwelling period may be given : Near the coast,

the very shallow, stabilized surface layers under the strongly overcast sky should allow, during the season of upwelling, a heavy development of phytoplankton, if the stabilization is maintained for some time, *i.e.* if the upwelling to the surface is not going on continuously : in the inshore waters, the thermocline is strengthened by the lowering of the surface salinity due to the river discharge, so that even in the turbid surface waters near the shore, the time of south-west monsoon is the season with maximum standing stock of phytoplankton. Leaving apart the November peaks of oxygen saturation in the observations of Kasturirangan (1957), the connection between stability and phytoplankton can be seen even from these monthly average values (as far as low salinity can be taken as an indication of stability, and the oxygen values as the indication of phytoplankton production) : Largely, oxygen peaks are accompanied by lowered salinity.—All previous authors report from Calicut repeated blooming of phytoplankton during the SW-monsoon season which is to be expected by the irregular break-down of suitable conditions due to new upwelling water. The November maximum of oxygen saturation found off Calicut might represent the balance between production and consumption of oxygen under stable conditions ; the daily production of phytoplankton may still be fairly high due to the amount of phosphate and nitrate present (average values of nutrient content are given by Subrahmanyan, 1958).

Observations on the annual cycle of the phosphate content off Calicut are available for a period of 7 years (George, 1953 ; Seshappa and Jayaraman, 1956 ; Jayaraman and Seshappa, 1957 ; Suryanarayana Rao, 1957, with total phosphorus ; Subrahmanyan, 1958). They show the yearly maximum of surface phosphate values to fall into the months of June and July during 4 years ; in the remaining years it occurred in August or September (monthly means well above 1 μg-at. P/L upto 1.9). In 1954, the phosphate maximum in September (monthly average 1.9 μg-at. P/L at the surface, 3.1 near the sea-bed at 15 m) was preceded in August by the maxima of total phosphorus of 9.5 and 10.4 μg-at. P/L respectively. (Suryanarayana Rao, 1957).

Consideration of weekly averages as given by George (1953) shows that already in May the phosphate content of the surface water can go up to nearly 1 μg-at. P/L respectively 1.5 in the following year. From George's Figure 2 it becomes evident that the frequent peaks of phosphate concentration during SW-monsoon cannot be related to the occurrence of low salinities ; so the river discharge during this time is not the cause of the high phosphorus level of that region. This was already stated by Suryanarayana Rao on the basis of direct analysis. But from the observations of George during 1949 and 1950 it appears that high phosphate values during SW-monsoon are often accompanied by a decrease of surface temperatures. Thus the upwelling is a main source of the high surface values of phosphate. The high phosphorus content of the bottom water is brought to the surface intermittently (see Figs. 2—4, George, 1953), as it is usual with upwelling elsewhere.—As mentioned earlier, the inshore water, in the interval between two intrusions of cold upwelling water into the surface layers, is stabilized and allows a plankton bloom which off Calicut within some days does not consume the enormous amounts of phosphate available, so that there is no inverse relationship between the plankton and that nutrient salt. In the post-monsoon time, when the upwelling is over, the phosphate content also in this area seems to vary inversely with the amount of diatoms present as suggested by George (1953) though the phosphate figures never will reach zero.

The phosphate concentration in the upwelling water approaching the shelf in 1958 cannot be stated with great accuracy due to the small number of observations at hand ; it varied in 1958 in the coldest water met with between 2.0 and 3.5 μg-at. P/L (corrected for salt error). The observations of Suryanarayana Rao (1957) suggest that on the shelf the break-down of total phosphorus into phosphate may have a bearing on the figures of the latter during this season.

Seshappa and Jayaraman (1956) found during one year of observations off Calicut a considerable variation of phosphate content in the bottom mud ; the figures of interstitial phosphate were lowest during SW-monsoon. It may be noted that the simultaneous observations on the phosphate content of the water close to the sea-bed show that the highest values were not reached in June or July when the stirring up of the mud should be most effective but only later (The pH-minimum in the mud was found in April to June, and minima of interstitial phosphate in June-July). The maximum figures of 2.4 to 3.5 μg-at. P/L stated by the authors for the water above the sea-bed are similar to the estimations in the off-shore deep water mentioned earlier. Also this observation is in favour of the above statement that the main source of the high phosphate content of that area during SW-monsoon is due to upwelling ; it can cause the initial rise of phosphate figures at the onset of the season, and it serves during many months as the source of replenishment, the existence of which has been postulated by Jayaraman and Seshappa (1957). It may be mentioned that even without being indicated by a marked decrease of surface temperatures, *i.e.* without proper upwelling, during SW-monsoon the cross-circulation in the coastal current off the west coast of India continuously will bring small amounts of deep water, rich in nutrients, to the surface.

In 1958, nitrite too has been estimated but the distribution is not easy to understand, as it often happens with this nutrient salt. The maxima of concentrations frequently met with at intermediate depths indicate that rather quick changes can take place. The cold water approaching the shelf is not supplying nitrogen in the form of nitrite, as observed in November/December 1958 in deep water beyond the shelf (see also Gilson, 1937).

Finally, it may be noted that the water enriched with nutrients by the strong upwelling south of about Quilon will be swept by the current beyond the continental slope south of Cape Comorin ; it is to be expected that in this season more plankton will be found south and southeast of India than farther west at the same latitude.

Upwelling and Demersal Fishes

In the introduction it was mentioned that the demersal fishes were supposed to be affected by the low oxygen figures of the bottom water. This view was supported by the experience of the trawling operations off Cochin, introduced in 1956, according to which, with the onset of the SW-monsoon, the demersal fishes used to disappear suddenly from the shallow areas. It happened also in 1958, in the middle of June, and when the trawling off Cochin was resumed in the beginning of September, fish (mainly *Synagris japonicus*) in appreciable quantities (>25 lbs per hour of trawling by 35′ vessels) was got in deep water only (about 35 m and deeper). Subsequently, the depth figure beyond which fish was found, varied ; during September and after

October 10, heavy catches (often > 1000 lbs per haul) usually were obtained beyond 25-35 m depth, whereas in the shallower waters, all efforts were in vain.

As an example of pronounced fluctuations of the depth limit within which fish (and prawn) were not caught, the fishing operations in the first ten days of October 1958 may be described in detail (result of the trawling of about 5 vessels with 2-3 hauls per day each if no heavy catches were made): On Sept. 30, the catches at 27-29 m and deeper often amounted to > 1000 lbs per trawling hour, as in the preceding weeks. On Oct. 1, all operations upto 38 m depth were in vain (figures from deeper water were not available). On Oct. 3, again heavy catches ($\geqslant$ 1000 lbs) were obtained at 28 m and deeper, and even at 20 m, 120 lbs were caught per trawling hour. On Oct. 6 and 7, all efforts between 13 and 46 m depth (from deeper water no results were available) practically did not produce any fish or prawn whereas on Oct. 10, beyond a very sharp limit at 29 m depth, again large quantities of fish were caught. After the 10th of October, the conditions remained, apart from minor fluctuations, the same as in September.

On Oct. 7, exploratory trawling was undertaken along a section given in Fig. 3, by a vessel kindly placed at my disposal by the Indo-Norwegian Project. In the top of the figure, those stations are marked by 'x' where 30 minutes trawling was done; simultaneously, hydrographic observations were run by R.V. *KALAVA*. The first haul at 14 m depth contained two serpents, the second one at 19 m one young Kalava (*Serranus* sp.), the third one at 30 m nothing, and only the fourth one at 45 m depth brought some pounds of Kilimeen (*Synagris japonicus*). The oxygen content 2 m above sea-bed was 0.20, 0.10, 0.25 and 0.40 ml/L resp. (accuracy $\pm$ 0.05 ml/L).

On Oct. 29 and 30, between 7 and 47 m no fish or prawn was found, whereas on resuming the operations on Nov. 3, and on subsequent days, hauls approaching 1000 lbs per hour were obtained at depths between 7 and 22 m. The first hydrographic observations after Oct. 7 (Fig. 3), on Nov. 3 (the section across the shelf upto 60 m depth not included in Fig. 1) revealed that at all stations near the bottom warm water rich in oxygen was present. The density distribution indicated current to the north and sinking of surface water. Thus, the definitely favourable conditions for trawling were established off Cochin within two days.

The reason for the quick disappearance of the demersal fishes at the beginning of the monsoon season, as well as for the shifting of the populated area, and for the observed sudden establishment of normal conditions are not to be looked for in the effect on the fish of the SW-monsoon itself. From the operations performed by two Ceylonese trawlers during many years on the Wadge Bank (*i.e.* the shelf south of Cape Comorin, *vide* Sivalingam and Metcof, 1957) it is seen that during SW-monsoon both the total catch and the catch per unit time of trawling are about twice that of the intermonsoon period and the NE-monsoon season; this is due to the appearance of migrant fishes mainly of the family Carangidae. The hydrographic conditions on the Wadge Bank during the summer monsoon would be similar to those met with south of Quilon (see Fig. 2). Neither the upwelling itself nor the low temperatures in the bottom water are influencing the distribution of the fishes which in 1958 were caught off Cochin, as seen from Fig. 3: The temperature decreased towards the region where fish occurred (the differences in the salinity of

the bottom water were nil). Also the distribution of the bottom fauna cannot be responsible for the quick changes in the area where demersal fishes were caught during upwelling, and for the sudden recovering of the fishery in November. Also for the Soles, *Cynoglossus* spp., during the end of the SW-monsoon season, a sudden return to the shore is the rule along the Malabar Coast (George, 1958).

It appears that the upwelling only indirectly exerts a governing influence on the distribution of the demersal fishes. Its low original oxygen content is further depleted on the shelf so that the fish could no longer stand the bad aeration of the bottom water. By plotting the trawling results off Cochin for September and October, 1958, against dates and depths (the original drawing cannot be given here), and comparing it with the oxygen values observed close to the sea-bed, it is seen that fish was found only when the oxygen content was above 0.25-0.50 ml/L (about 5-10% of the saturation value); owing to the comparatively few oxygen estimations, a more accurate statement is not possible. The bulk of the catch concerned was made up by *Synagris japonicus* (about 93% of the total catch of the trawlers), followed by *Platycephalus* spp. (about 4.5% of the catch).

According to the daily reports of the trawlers of the Indo-Norwegian Project, principally, the same distribution of demersal fishes, as in 1958, was met with in 1956 and 1957. In June 1956, the disappearance of fish within a few days upto about 40m was rather well marked (in this year, the places of trawling were chosen nearly at random), whereas in 1957 in depths $<$20m, probably the fish disappeared one or two weeks earlier than from the deeper water. At the end of the season, in 1956 and 1957, the area of profitable trawling moved slowly from the deep water towards the coast, as well as from the region off Alleppey northward to Cochin. In all three years, the disappearance of fish from the shallower parts of the area coincided, within a very few days, with the onset of the SW-monsoon along the coast; in 1958, the sudden reappearance of demersal fishes followed the activity of a depression in the Bay of Bengal. During this time of the year, the summer monsoon circulation is finally broken down by such disturbances.

In 1957, in the region inside the desolated area, trawling was very profitable. Due to the origin of the aerated belt near the shore (see p. 40) its seaward extent varied considerably, sometimes reaching to 15 m depth. Because of the changed region of trawling the composition of the catches was of another type compared with 1958 when all efforts in the inshore waters failed. For 1956, no compilation of catch composition is available.

The hatched area, in Fig. 1 (from the observations of 1958) shows, based on the oxygen determinations, the extent of the region where bottom trawling, probably, would have been unprofitable during the visits to the respective places, between the beginning of September and the beginning of October, 1958. Based on the experience of three years and on the discussion on the extent of upwelling in space and time, it seems justified to regard the rather sketchy indication of an area devoid of demersal fishes as the representation of a typical feature of the marine biology of the Malabar Coast. It may be emphasized again that the limiting oxygen values have been derived mainly from the distribution of *Synagris japonicus*; but because oxygen values of $\leqslant$0.25 ml/L have been frequently met with, the distribution of other species, very probably, is also affected which is indicated

by some observations mentioned below. In Fig. 1, off Cochin, the average limit of that area during the period of observations could be given, whereas seaward of the stations 332 and 333, off Calicut, the position of the border is unknown. (At these stations, the oxygen had completely disappeared from near the sea-bed). The continuation of the desolated area towards north is also uncertain but according to the hydrographic evidence, nearly the same conditions as along the Malabar Coast will prevail upto Goa. Off Bombay, north of that area from where upwelling is definitely known, the rising of the deep water on the left side of the coastal current may cause similar biological conditions near the sea-bed as off Cochin, as pointed out on p. 40. This will not necessarily become reflected by changes in the very surface layers.

The relation between the oxygen figures and the depth distribution of successful hauls in the operations off Cochin during 1958 suggests that it should be possible, on the basis of occasional hydrographic sections across the shelf during SW-monsoon, to direct the working of the trawler fleet to some extent so that the number of unsuccessful hauls may be reduced. It was not possible to correlate for 1956-58 the daily observations on surface temperature and surface current done by the trawlers themselves, to their catches during SW-monsoon. For the temperature this result was to be expected because, during periods of stabilization of the upper water layers, the surface temperature varies practically independently of the conditions prevailing below the discontinuity layer.

It would be worth investigating as to what happens to the populations of demersal fishes when the badly aerated water in June suddenly covers the shelf and deteriorates there. Reports on regular large-scale mortality of fish during this season have not been published. Therefore, either the fishes (and prawns) are pressed against the shore, or are migrating to deep water. Mid-water life does not seem to be maintained for a long period even if it occurs.

The presence of an inshore trawling area in 1957 testifies to the first possibility, as well as the observation of Seshappa (1953) that in 1950 the mud-goby *Trypauchen vagina* appeared in the inshore area at Calicut with the onset of the monsoon conditions. This species has been found by Kurian (1953) to live at a depth between 8 and 25 m. Finally, Krishna Menon (1958) states that on the Malabar Coast, from June to August, fishermen frequently catch prawns with cast nets, *i.e.* in quite shallow water, because the shoals come near the shore at this time of the year. It is also true that the yield of fish caught by country crafts in the shallow inshore waters is affected during the season of SW-monsoon (see Bhimachar and Venkataraman, 1952). It seems to me worth while to investigate more closely, on the basis of the already available data, and taking into account the biology of the species (f. i. demersal *versus* pelagic fishes), the events happening within the area depleted of oxygen. Perhaps it is even possible to find out by this method how far to the north the same biological offshore conditions as along the Malabar Coast are to be expected.

The heavy catches of the trawlers of the Indo-Norwegian Project, during three years in offshore waters, indicate that the fish, after the commencement of the unsuitable conditions near the sea-bed in near shore waters, can also migrate to greater depths (here, a close investigation on the composition of the catches, as

compared with that of the other seasons is desirable). Also among the crustacea this might happen : For the purely marine prawn, *Parapenaeopsis stylifera*, it was stated by Krishna Menon (1953) that the younger animals begin to leave the inshore area towards the end of May, after the commencement of the SW-monsoon, followed by the older individuals so that from July onwards only very few specimens are to be caught there. They return in October. Table I of Bhimachar and Venkataraman (1952) gives an example for the decline in the catch of prawns in June off Calicut. The reason for this migration is not known.

Regarding the possible resorting of fishes to mid-water life, George (1958) stated with reference to the soles (*Cynoglossus* spp.) that these demersal fishes disappear from the shore during the onset of the SW-monsoon, and return when its vigour has passed. They return by mid-water, not along the bottom. Usually, they reach the coast in August-September ; in 1958, they arrived at the shores near Mangalore during the last days of September, but they were not present at Calicut during the period of hydrographic observations, Sept. 30-Oct. 2. Resorting to mid-water life is usual with the Baltic cod when the bottom water becomes badly aerated. It is felt that this change in behaviour is not maintained for a long time by the fishes of this area because, in the cruises in 1958, we did not see mid-water traces of fish in the echo-sounder in the area in question.

It is obvious that only some members of the bottom fauna can stand the complete depletion of oxygen from the water near the sea-bed (stations 332 and 333), and also these species would tolerate it only for a limited time. Off Calicut in 1950, Seshappa (1953) did not observe complete disappearance of the bottom fauna at 15 and 18 m depth. This happened only in shallower water and was supposed to be due to the unstable sediment during the time of SW-monsoon. But the wet weight of bottom animals (including shells) of 2.5 and 2.8 g/m^2 at 15 and 18 m depth (October and September 1950, respectively) is rather low, compared with the maxima of 43.5 and 25.8 g respectively during May. Seshappa suggested that the lowering of wet weights at 15 and 18 m depth was not caused by the whirling up of the sediments. So it may be that there occurs mortality among the bottom fauna due to bad aeration of the bottom water. Observations from deeper water are wanting. It may be noted that Seshappa observed from the shore dying of crabs in June 1949 ; one of the species, *Neptunus sanguinolentus*, was stated by Krishna Menon (1952) to be practically absent from the inshore waters after the onset of the monsoon rain. Kurian (1953) found it to live at depths between 10 and 25 (30) m. So it would seem that, sometimes, this species is also pressed against the shore during SW-monsoon season. Seshappa concluded the discussion of his observation by suggesting that the death was not due to the release of deleterious substances from the agitated mud, because, some days later, following the final disappearance of the mud bank off West Hill, immediately fishing activities were resumed in that region.

Summary

It is shown that off the west coast of India, from 8° to at least 15° N, strong upwelling is regularly observed during the whole south-west monsoon season, *i.e.* for about five months. The oxygen content of the upwelling water which comes from near the upper intermediate oxygen minimum layer, is further reduced by the increased oxygen consumption on the shelf. As a result, off the south-west coast of India

demersal fishes have been found to disappear from a rather broad belt parallel to the coast. Therefore, during this season, bottom trawling is profitable only in deeper water, and occasionally in very shallow water too. Further, it is shown that the high phosphate content at the surface, regularly observed off the west coast of India during south-west monsoon, is mostly due to the upwelling.

Addendum :

After the manuscript was given to the press, I received the paper of Carruthers, J. N., Gogate, S. S., Naidu, J. R., and Laevastu, T. : ' Shorewards upslope of the layer of minimum oxygen off Bombay : Its influence on marine biology, especially fisheries ', Nature **183**, 1959, 1084-1087. The authors observed upwelling off Bombay. During the entire period of observations, from Oct. 24 to Nov. 11, 1958, they found stable hydrographic conditions, the isolines of the investigated properties rising towards the coast. On October 24, near the bottom of a station with 42 m depth, they measured a current speed of one-third knot (direction towards 210° magnetic). It may be added here that at Bombay, according to the ' Indian Daily Weather Report ' (Meteorological Office, Poona), during the period of observations the surface wind steadily exhibited, at 0830 IST, a direction from NE or E (N), and a speed of 2-7 knots, and at 1730 IST, a direction from about NW, and a speed of 4-10 knots.

On p. 37 it was indicated that off Bombay upwelling to the surface will occur only from August onwards. It appears that in 1958 the NE-monsoon which may regularly cause upwelling off Bombay also (Jayaraman and Gogate, 1957), started there before the SW-monsoon current patterns along the west coast of India was changed. That will facilitate the bringing up of the depth water to the surface. It may be recalled that the upwelling off Cochin, in 1958, ended in the very first days of November, probably in connection with the reversal of the coastal current pattern.

ACKNOWLEDGEMENT

As a scholar under the Indo-German Industrial Co-operation Scheme, and sponsored by the German Research Association, I wish to express my sincere thanks to the Central Marine Fisheries Research Station, Government of India, and to the Indo-Norwegian Project for the facilities placed at my disposal on land and at sea. The chlorinity and oxygen titrations were performed by Mr. C. P. Ramamritham. The Indo-Norwegian Project gave the permission to use the daily reports of its trawler fleet.

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THE AQUALUNG : AN AID IN UNDERWATER EXPLORATION

By F. B. Salvadori*

The human body is not naturally adapted to life under water. The cave paintings do not give us any indication of the early men having made any attempt at underwater exploration. But, as soon as man reached the first steps in civilization he showed a desire to know the goings-on under the surface of the water. History shows that free-diving, viz., diving without the aid of any kind of apparatus or equipment, played an important part in the Hellenic world where it was first developed for sponge fishing ; even today, the divers of these coasts hold the record in the Mediterranean and in other seas for this type of fishing ! In the same way coral was fished centuries ago both in the Mediterranean and the Extreme Orient. Together with these two more or less contemporary forms of fishing, we have information of the fishing of pearls and varied types of shells for different ends. Even in Homer's Iliad the art of diving is held in honour. Those divers who attained celebrity and glory belong to the Greco-Roman period, some were even deified, for instance Glaucos together with Neptune. Scyllias and Cyana were famous for their bellicose underwater operations against the Persian army at Cape Artemisium.

More historical information on the employment of frogmen in battle comes from the pen of Thucydides in several episodes of the war between Sparta and Athens.

But if history has recorded these and numerous other accounts of man's free-diving, it gave us very little regarding experiments with breathing apparatus ; perhaps the oldest account is that of Aristotle, if the interpretation given to one of his passages is correct : ' The divers have even built themselves instruments by which they can remain longer in the water breathing the air that is to be found above the surface, as nature has given a trunk to the elephant which it uses for an analogous purpose.'

Whereas little is known about diving operations in the Occident during the middle ages, numerous instances of divers being employed for war and fishing purposes are recorded from the Orient.

Only with Leonardo da Vinci do the first drawings of underwater equipment appear ; however, viewed in the light of modern experience, these could not have been used for any kind of underwater work ; rather, they are more of the imagination. All the same, based on these, numerous immersion equipments were made, but the insufficient knowledge of that epoch regarding pressure etc., obstructed a solution to the various problems involved in diving. Perhaps, one of the first and most simple instruments invented was the diving bell by Borelli of Italy in the 17th Century : ' a submerged metal bell that did not touch the bottom, under which the diver could

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return to breathe without the necessity of returning to the surface.' Evolution in this field became ever more rapid and trials followed in quick succession, till, at the end of the 18th Century, the first practical apparatus could be used.

Finally in 1819, with Augustus Siebe, a definite apparatus fed from the surface by a pump came into being. Following this, in 1844, the first series of scientific dives in history took place—the great naturalist Milne Edwards dived repeatedly with the Paulin apparatus along the coast of Sicily.

In 1855-60, Benois Rouquayrol and Auguste Denayrouze built the first diving apparatus using compressed air. This prototype was the basis on which the modern aqualung, with subsequent modifications, was constructed.

The major development of underwater activity and inventions of better equipments could be put in a chronological order as follows :

(*a*) for bellicose purposes during World War II with oxygen apparatus, used first by the Italian Navy assault parties, then by the British, Japanese and Americans ;

(*b*) immediately after the war until today for sport and industrial purposes, *i.e.*, underwater spear-gun hunting, industrial fishing and salvaging ;

(*c*) and finally in the most recent years for scientific and general research purposes with the aqualung.

While for sport and some industrial purposes free-diving with mask and fins alone is sufficient, for research and salvage operations, one or other of the breathing apparatus is essential to allow the diver to descend to greater depths and remain there for greater duration. The modern equipment varies from the old type of surface-fed diving bells : from the most simple and practical method consisting of a rubber mask fed either by pump or by cylinders of compressed air from the surface, but allowing the diver more flexibility and independence of movement, to the most modern of all, the oxygen apparatus and the aqualung. The last two permit the diver complete freedom of movement for his underwater work. Each apparatus however serves its own purpose depending on the conditions, depth, duration and type of work in which the diver-specialist will be engaged, not forgetting the importance of the various economical factors.

There is, I think, no need to describe the surface-fed apparatus as they are by now well known to all ; a brief description however of the oxygen and air apparatus and some of their defects and merits might be of use to those who intend to carry out diving operations using them.

The oxygen apparatus is also called ' closed circuit-respirator ' because, the breathing channels of the diver together with the cavities of the apparatus form a closed circuit. This mainly consists of (*a*) lung-sack in rubber or rubberised canvas, (*b*) a metal purifying-filter, (*c*) metal cylinder containing compressed oxygen, (*d*) mouthpiece and mask, and (*e*) corrugated tube connecting the lung-sack to mouthpiece. The lung-sack has the function of distributing respiratory gas at hydrostatic pressure. The purifying filter contains grains of alkaline substances, usually calcium soda, to absorb the carbon-dioxide ; if this is not absorbed as and when formed, it would rapidly reach toxic concentrations. The oxygen in the lung-sack, consumed

by breathing, becomes renewed either by a system of continuous flow from the cylinder or as and when the diver breathes. This apparatus is commonly called the Davis Apparatus because it was Davis who, at the beginning of this century, made the necessary modifications to pre-existing types that enabled the apparatus to be used with such success as a means of escape from submarines. It is also used for speleological explorations. Compared to the air-apparatus, the closed-circuit-respirator presents the advantage of possessing fewer impediments and a higher autonomy of immersion. On the contrary it offers less possibilities of immersion at greater depths because, as is well known, oxygen at a pressure of about 2 kg. per sq. cm., can become toxic, and even at depths of 10 metres the apparatus may present considerable dangers to the human system.

As regards underwater scientific research, the explorer has to cover greater depths and therefore the air-apparatus, for the time being, the only type that permits several minutes stay at a depth of 60-70 meters with minimum risk if used rationally, is undoubtedly the most advisable form of equipment. Although present manufacturers are constructing the air apparatus or the Aqualung under different patents, all are working more or less on the same principle, i.e., the possibility of supplying air by means of a regulator from the reserve cylinder carried by the diver on his back to the diver's lungs only on demand following inhalation by him.

This apparatus notwithstanding its simple design and ample possibilities for work at greater depths, can at the same time present equal dangers if used imprudently ; one of the most common dangers being what is known as the ' bends '. The ' bends ' are liable to happen, when, after a long stay at great depths the diver returns to the surface too rapidly, a certain amount of inert gases like nitrogen dissolved in the blood stream during stay under pressure liberate in the form of bubbles causing osteo-muscular pains, disturbed breathing, paralysis and even death. The only sure way of avoiding such a condition is to adhere strictly to the Decompression Rules, i.e., the practice of halting during return to the surface at the stipulated depths and for the specified time, as indicated by the Decompression Tables (these tables are printed now-a-days by the Navy in most countries and by the Institutes of scientific research on the physiology and pathology of the human body in immersion).

Another more serious danger presented by the aqualung when the diver surpasses the depth limit of security, say 60-70 meters, is what is called ' rapture of the deep '. This phenomenon which manifests itself as a perfect state of drunkenness, causes a change in the diver's intellect, thereby inducing him to perform awkward impulsive actions at times without the minimum reflection. Dangerous because, such a state of mind may lead the diver to strip off his mask and mouthpiece or even to continue on the downward journey, unaware of his reflex actions in his new state of exhilaration. The cause of this ' rapture of the deep ' is not yet clear. There are various hypotheses, but for the moment, none is altogether convincing.

Although I have only mentioned about breathing apparatus and their evolution, there are other types of equipment essential for underwater research : Equipment like the spear-gun for the capture and collection of biological specimens. Underwater camera for photographic recording of life underwater. Depth meter for recording the depth at which the studies are made, and water-proof wrist watch to note the time of immersion. Modern science has contributed all these to enable the researcher to make a thorough study of underwater life through direct observations.

By means of these underwater equipments, particularly the aqualung and the underwater camera, the biologists as well as the hobbyist can explore, document and study the various forms of underwater life. The social behaviour of fish, fish locomotion, their breeding grounds, the pattern of distribution of life under water and the type of the sea bed are some of the more important studies for which the biologist finds the aqualung and similar underwater equipments most indispensable. During my short stay in India, I was able to have a general idea of the underwater life in Gulf of Mannar area. Though I was particularly concerned with the study of the chank and pearl beds off Tuticorin, India, yet, my general observations of the flora and fauna of these beds remind me of the Red-Sea areas which I visited in 1953 with the Italian National Underwater Expedition. Broadly, the pattern of distribution of life underwater in the Red-Sea areas stands parallel to that of the Indian waters ; especially so in the case of the coral beds of the Gulf of Mannar. It may be stated that there is much scope for detailed scientific studies of the underwater flora and fauna of the Indian waters because, these areas are not explored so far. Intensive underwater explorations, both for scientific as well as sportive purposes, have resulted in the depletion of stocks of numerous species of fishes in the Mediterranean Sea and hence, one is bound to come across many larger species in unexploited areas like the Indian waters.

One could derive endless pleasure and a mine of information watching the underwater life—the brilliantly coloured fishes that swim about, the graceful movements of the scorpion fish, the parrot fish amidst the coral beds, the corals themselves with a diversity of exciting formations and colours like the brain coral and the stag-horn coral, the sandy bottom with innumerable star fishes, red sponges, brilliantly coloured sea anemones, the hydroids and the various types of marine plants are some of the typical ' treasures ' of the sea. Only through photography can these be brought to the surface. Modern methods in underwater filming and television have enabled the scientists, who are unable to withstand immersion, to study the ocean beds and the mysteries of underwater life.

As we have seen the first official underwater research was carried out by Milne Edwards in 1844, but it is only in the last few years that a serious attempt has been made to employ underwater equipment in a field other than industry or sport. The possibilities in this new field are as vast as the sea itself. The institutions that conduct underwater research with positive results are few. The notable among these are L' Office Francaise de Rechérches Sous-marins, founded by Commandant Yves Cousteau in 1952 at Marseille, the Scripps Institute of Oceanography at La Jolla in California, Instituto Internazionale di Studi Liguri at Bordighera, L' Institute de Rechérches Sous-marins at Cannes, the Internationales Institut fur Submarine Forschung at Vaduz in Liechtenstein, and Il Centro-Italiano Ricercatori Subacquei at Genova. Looking into the past and over the horizon of the future, it is doubtless that other institutions will spring up in countries where a desire exists to elevate and augment their own scientific advancement.

J. Mar. biol. Ass. India, 1959, **1** (1) : 54-56

AMINO ACID CONTENTS OF THE ERECT AND CREEPING FRONDS OF SPECIES OF *CAULERPA* FROM BOMBAY

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Introduction

In recent times, several papers have appeared on the amino acid contents of algae, but so far, there has been practically no record of the distribution of amino acids in the different morphological parts of one and the same alga. Since the species of *Caulerpa* can be conveniently differentiated into erect fronds and creeping fronds, they were selected for study. An attempt was made to ascertain whether the amino acid contents in the different parts of one and the same plant show any variations in their concentrations. The erect fronds and creeping fronds of three species were analysed separately and the results were compared with those of a previous investigation for the entire plant (Lewis and Gonzalves, 1959).

Material and Methods

The specimens selected were *Caulerpa racemosa* (Forsk.) J. Ag. var. *uvifera* (Turner) Weber-van Bosse f. *condensata* Weber-Van Bosse (Collected on 2-2-1956, Colaba, Bombay) ; *Caulerpa peltata* Lamour. var. *typica* Weber-van Bosse (2-3-1956, Colaba, Bombay) ; and *Caulerpa sertularoides* (Gamel) Howe f. *typica* Boergs. (5-1-1956, Colaba, Bombay).

The specimens were growing in abundance on rocks near the low-water mark on the shores of Bombay. They were collected, cleaned and the erect fronds were separated from the creeping fronds. Each of these parts was dried separately, powdered and preserved.

The experimental methods followed and chromatographic technique used were according to Lewis and Gonzalves (1959).

Results

The analytical results are given in Table I and the results are calculated on the basis of per cent dry weight of algal powder.

Discussion

A comparison of the results with those for the entire plants (Lewis and Gonzalves, 1959) revealed, in all, twenty amino acids in the three species of *Caulerpa* and its various parts. Hydroxyproline was undetected in the entire plants and erect fronds

of *Caulerpa racemosa* and in the entire plants of *Caulerpa sertularoides*. Its absence in the entire plants seems inexplicable, since it was found in some of the separated parts of the same plants. However, as it occurs in traces, it is likely that its presence escaped detection.

Of the twenty amino acids recorded, alanine, arginine, aspartic acid, glycine, glutamic acid, histidine, isoleucine, leucine, methionine, phenylalanine, proline, serine, threonine, tyrosine and valine are found to be major constituents ; cystine and lysine are minor constituents ; while hydroxyproline, ornithine and tryptophan are in traces. These observations are in agreement with those of Lewis and Gonzalves (1959).

TABLE I

PERCENTAGE OF COMBINED AMINO ACIDS IN THE ERECT AND CREEPING FRONDS OF SPECIES OF *CAULERPA*

(Calculated on the basis of per cent dry weight of algae)

Amino acid	*Caulerpa racemosa* var. *uvifera* f. *condensata*		*Caulerpa peltata* var. *typica*		*Caulerpa sertularoides* f. *typica*	
	Erect fronds	Creeping fronds	Erect fronds	Creeping fronds	Erect fronds	Creeping fronds
Alanine	0.98	0.68	1.57	1.14	1.31	0.91
Arginine	0.76	0.74	1.23	1.45	1.30	0.87
Aspartic acid	0.88	0.83	1.31	1.11	1.37	0.95
Cystine	++	++	++	+++	0.38	0.16
Glycine	0.65	0.55	1.15	1.07	1.10	0.65
Glutamic acid	0.54	0.52	1.52	1.49	1.00	0.67
Histidine	1.44	1.35	2.12	2.54	1.66	1.40
Hydroxyproline	—	++	+	++	+	+
Isoleucine	0.53	0.40	1.11	0.74	1.80	1.24
Leucine	0.56	0.43	1.16	0.78	1.80	1.54
Lysine	0.66	0.78	0.84	0.78	0.17	0.13
Methionine	2.26	1.79	3.47	3.28	3.08	1.88
Ornithine	++	++	++	++	++	++
Phenylalanine	0.87	0.65	1.57	1.08	1.25	0.67
Proline	3.80	1.31	5.43	5.01	5.63	3.18
Serine	1.11	0.74	0.61	0.59	1.00	1.00
Threonine	0.77	0.91	1.38	1.00	1.18	0.74
Tryptophan	++	++	+	+	+	+
Tyrosine	2.64	2.10	6.27	5.49	3.88	2.83
Valine	0.92	0.89	1.66	1.04	2.45	1.26
Total number identified	19	20	20	20	20	20
Total amount estimated	19.37	14.67	32.40	28.59	30.36	20.08

The concentration of arginine, aspartic acid, cystine, glycine, serine and valine did not vary appreciably in the different morphological parts of *Caulerpa racemosa*, but appreciable variations in the concentration of the other amino acids were observed. Cutting appreciably affected the concentration of all amino acids, except

cystine, glycine, methionine and tyrosine in *Caulerpa peltata* ; while cutting appreciably affected almost all amino acids in *Caulerpa sertularoides*.

It was observed that the entire plants, erect fronds and creeping fronds of one and the same alga contained combined amino acids in decreasing concentrations. The lesser amounts in the erect fronds and creeping fronds may be due to the loss of sap, which escaped during the cutting operation. The higher concentration in the erect frond is to be expected as it is the seat of metabolic activities.

Summary

The erect and creeping fronds of three species of *Caulerpa* found on the shores of Bombay were analysed separately by paper chromatography. In all, twenty amino acids were detected. Of them, fifteen were found to be major constituents, two minor and three in traces. The concentration of amino acids was found to be higher in entire plants than in either of the cut portions, and greater in the erect fronds than in the creeping fronds. The loss observed after cutting the specimens might have been due to the loss of sap which occurred when the specimens were cut.

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J. Mar. biol. Ass. India, 1959, **1** (1) : 57-65

ON TWO NEW SPECIES OF *CLAUSIDIUM* (COPEPODA : CYCLOPOIDA) PARASITIC ON THE SHRIMP *CALLIANASSA*

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The genus *Clausidium* includes seven species, *C. apodiforme* (Philippi) from the Mediterranean and Adriatic seas, *C. caudatum* (Say), *C. vancouverense* (Haddon), *C. dissimile* Wilson, *C. searsi* Wilson and *C. tenax* Humes, all from the North and South Americas and *C. senegalense* Humes from West Africa. The present record extends the distribution of the genus to the Indian Ocean and brings the total number of species known to nine.

Genus *Clausidium* Kossmann

Clausidium, Wilson, 1921, p. 425.

Clausidium, Light and Hartman, 1937, p. 173.

Clausidium, Humes, 1949, p. 93.

The genus possesses the following characters :—Body oval and much flattened ; first thoracic segment united with the head, second and third free, short, fourth and fifth covered by a dorsal plate, sixth segment narrow and partially visible ; abdomen one to three segmented, segmentation indistinct ; egg sacs short, eggs in several rows ; antenna one normal, seven segmented ; antenna two modified, four segmented, distal segments with long setae ; legs one to four biramous, with sucking discs, first pair highly modified, fifth leg uniramous, two segmented.

Male generally like the female, usually remaining attached to the female ; dorsal plate covering the fourth and fifth thoracic segments distally bilobed ; sixth segment with rudimentary legs ; abdomen three segmented ; appendages generally like those of female but the maxilliped modified as prehensile organs.

All the species so far recorded are parasites of the shrimp belonging to the genus *Callianassa*. The copepod is light red in colour and remains attached to the gills. In majority of cases the male remains attached to the abdomen of the female and does not relax its hold even on throwing the specimens into the fixing fluid. On superficial examination the male appears as a part of the female, very much like the swollen genital segment of *Caligus* spp.

Clausidium travancorense sp. nov.

(Figs. 1-2)

Female:

Body oval, posterior part slightly narrower than the anterior, anterior border perfectly rounded. Dorsal surface with minute spines, more towards the peripheral parts. First thoracic segment with the head together slightly less than half the length

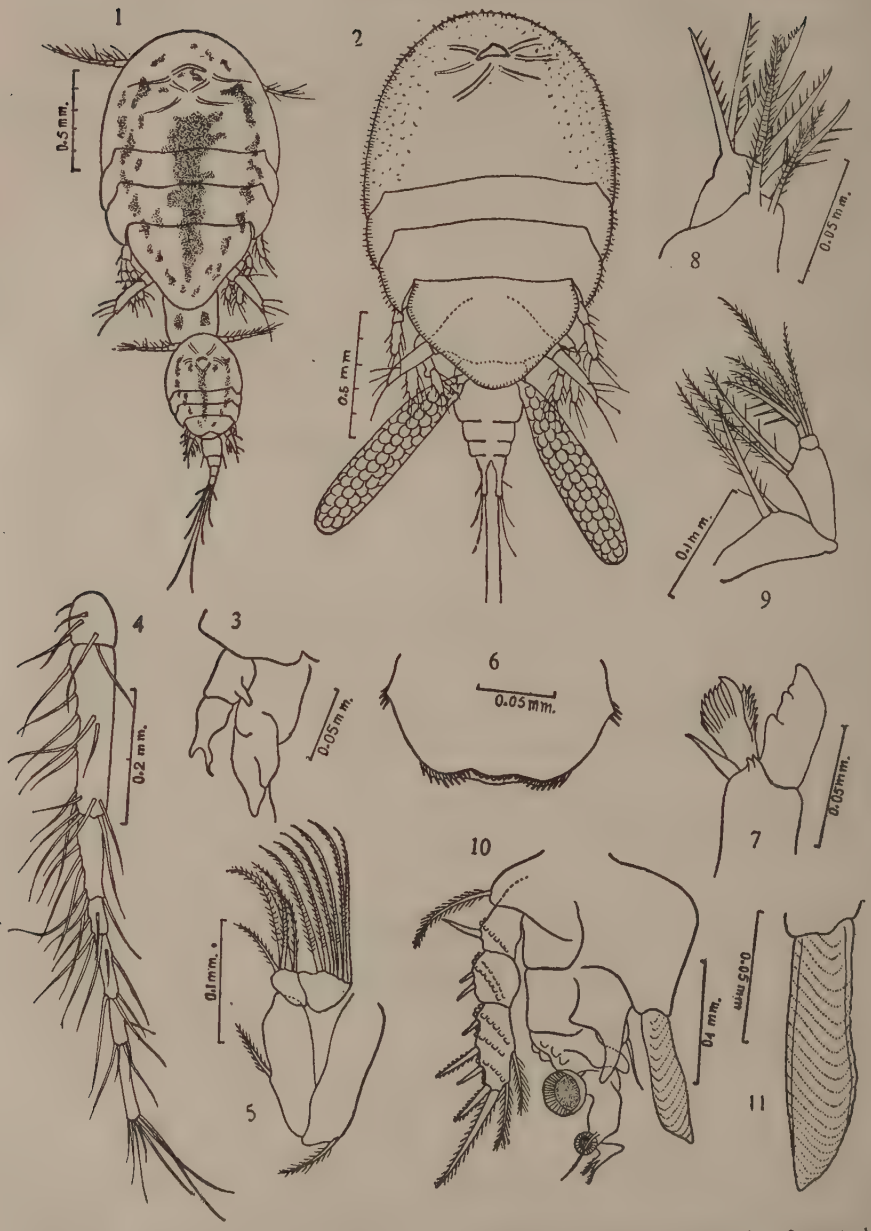

FIG. 1. *Clausidium travancorense* sp. nov. 1, male and female *in situ*. 2, female. 3, ventral view of abdomen showing appendages. 4, antennule. 5, antenna. 6, labrum. 7, mandible. 8, second maxilla. 9, maxilliped. 10, first leg. 11, same, blade like seta.

of the cephalothorax. Segments two and three narrow ; posterior border of dorsal plate rounded and reaching the proximal part of the sixth thoracic segment. Sixth segment rectangular, longer than broad. Postero-lateral angles of first three segments produced and angular. Abdomen short, narrower than the sixth thoracic segment, segmentation indistinct and with two pairs of degenerate appendages. Basal part of caudal rami bulged, each with one small outer and three long apical setae. Ovisacs apically rounded.

First antenna with the second segment nearly equal to the next three segments combined, fourth segment shortest. Second antenna with the first two segments subequal, each with one seta, segments three and four short, former with four and the latter with six setae, all the setae pectinate, one on the third segment stouter than the others. Labrum about one and a half times as broad as long, with a pronounced lateral bulge carrying a row of short spines, distal border trilobed, lateral lobes with sharp spines and the median lobe with blunt teeth. Mandible with an elongated basal limp carrying two flattened processes, outer process flat, internally concave and with two to three blunt cusps, inner and distal borders of inner lobe serrated and the inner surface corrugated, outer border with a serrated accessory lobe; a conspicuous spine and two small teeth also present at the base of the inner lobe. First maxilla as in *C. senegalense* Humes. Second maxilla two segmented, first segment with three stout setae, two pectinate and one barbed ; distal segment with a stout bifid spine, strongly barbed on one side, and two large barbed setae above and a similar one below. Maxilliped four segmented, first two segments subequal and similar, each with two setae, one of them stout and pectinate, and the other slender and plumose. Last two segments very small, third segment with two slender setae and the fourth with three setae, two of them large and one small, the large inner seta barbed.

First pair of legs modified for prehension. Basipodite very broad, rami three segmented, endopodite much flattened and modified and the segmentation indistinct. First segment of exopodite with one spine and an oblique row of tubercles, second segment with two spines and two rows of tubercles. First segment of endopod with one stout outwardly curved process and the second with an inwardly curved process and a seta, third segment narrow and with two suckers, first larger than second; apex with three setae, the two distal ones bent and pectinate. Inner blade like process arising from the inner corner of the basipodite almost reaching the level of the distal sucker of the endopod, distally tapering to a blunt apex, its surface with parallel lines or striations. Legs two to four with the following setal formula.*

No. of the segment	Leg II		Leg III		Leg IV	
	Exo.	Endo.	Exo.	Endo.	Exo.	Endo.
1	1,0	S,1	1,0	S,1	1,0	S,1
2	1,1	0,2	1,1	0,2	1,1	0,2
3	8	2S,6	8	2S,6	9	2S,5

*S represents suckers and the numbers represent the total number of spines and setae.

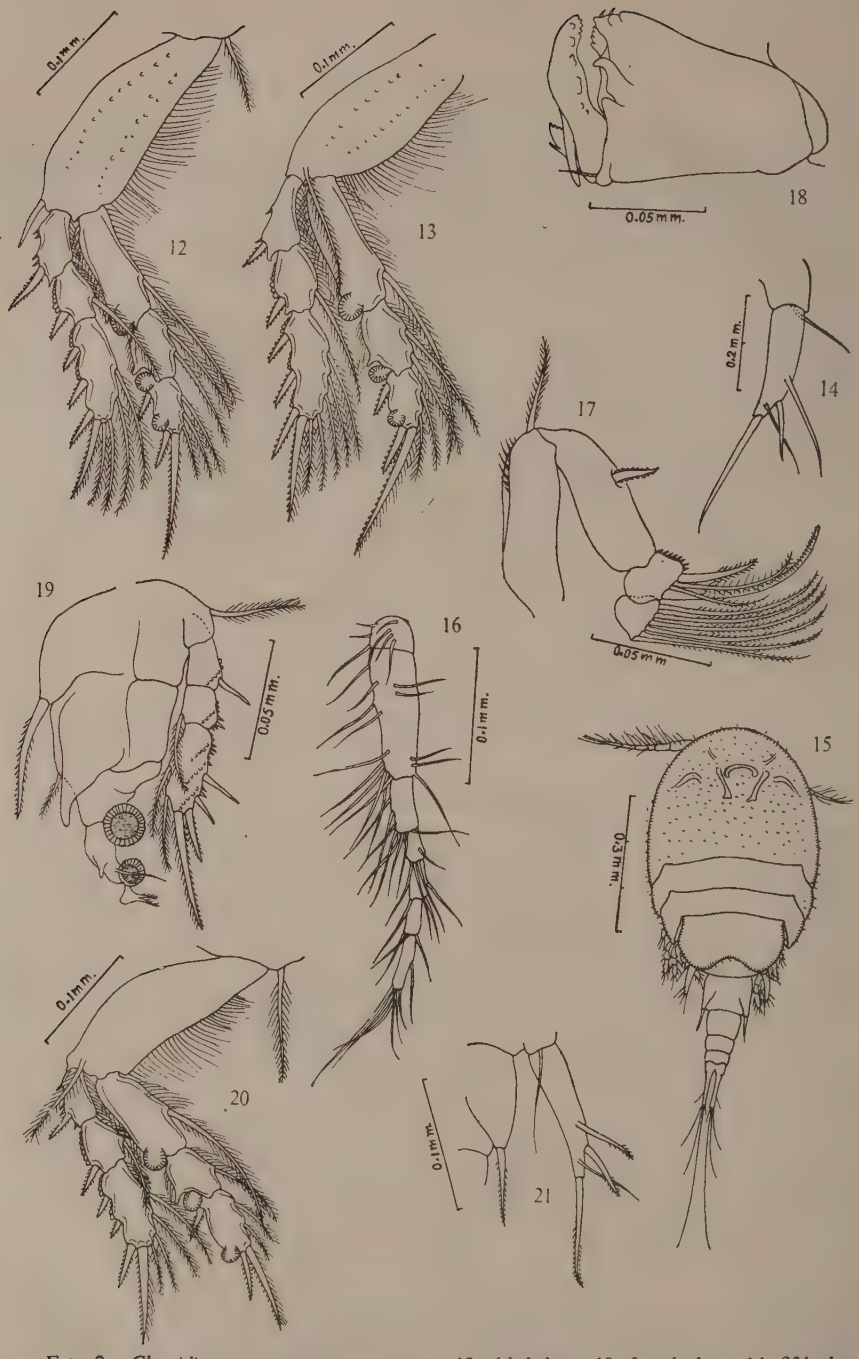

FIG. 2. *Clausidium travancorense* sp. nov. 12, third leg. 13, fourth leg. 14, fifth leg. 15, male. 16, antennule. 17, antenna. 18, maxilliped. 19, first leg. 20, fourth leg. 21, fifth leg.

Fourth leg differs from the others especially in the third segment of the exopod which carries five setae and four spines making in all nine ; the maximum in all the other species is eight.

Fifth leg uniramous and two segmented, first segment scarcely visible beyond the plate covering the fifth thoracic segment. Second segment nearly parallel sided, tapering to the tip, the outer edge with three stout spine setae and a slender hair, basal segment with a long slender seta.

Male :

Body oblong, dorsal surface more spiny than that of female. Cephalon and first peraeon segment together slightly more than half the length of cephalothorax ; dorsal plate twice as broad as long, posteriorly bilobed, not completely covering the fifth peraeon segment. Sixth peraeon segment squarish, with a pair of appendages. Abdomen three segmented, caudal furca as in female, but longer and more slender, distal setae very long.

First antenna as in female. Second antenna like that of female but the seta on the second segment modified into a serrated stout spine. Inner border of third segment spiny and one of the four setae very stout and transversely grooved, fourth segment with six long pectinate setae. Mandible and maxillae as in the female. Maxilliped greatly modified, with a large basal segment broadening distalwards, distal border irregular, its inner distal corner produced and toothed, the mobile process long, with five to six blunt teeth and its distal margin serrated. At the base of the mobile process is a toothed blade directed towards the tip of the mobile process and another elongated process pointing in the opposite direction.

First leg like that of female, but the second segment of exopod with an inner seta ; blade like process replaced by a stout pectinate seta and the third segment of endopod with a blunt median process. Legs two to four similar, very much like those of the female, third segment of exopod of fourth leg with only four setae. Fifth leg like that of female but more slender and the three stout setae distally pectinate.

Length of female 1.76 mm., male 0.95 mm.

Material

Seven males and seven females were obtained from the gills of *Callianassa maxima* M. Edwards, collected from the bar mouths of the Kayamkulam and Ashtamudi lakes, Kerala State.

Remarks

The males of all the species of *Clausidium* resemble closely that they provide very little help in specific diagnosis. The maxillipeds, however, show specific variation and its minute structure is important. The maxilliped of *C. travancorense* sp. nov. is different from that of all the species known. In the shape of the mobile process and the toothed inner corner of the basal segment, it resembles that of *C. senegalense* Humes to some extent. But in the new species the basal segment is different in shape and at the base of the mobile process there are two processes which are absent in *C. senegalense*. In the latter character *C. tenax*, *C. apodiforme*, *C.*

dissimile and *C. caudatum* also differ from *C. travancorense*. This basal process is present in *C. vancouverense* but in this species the maxilliped is otherwise totally different.

The female of *C. travancorense* is much similar to that of *C. senegalense* but the mandible is very much like that of *C. tenax*. Also the fifth leg of *C. senegalense* is stouter than that of *C. travancorense* and shows marked sexual dimorphism unlike as in the new species. The fifth leg of the new species is more or less like that of *C. apodiforme* and *C. dissimile*. The short abdomen and the presence of five setae on the third segment of the exopod of the fourth leg of the female and the maxilliped of the male distinguish *C. travancorense* from all the known species.

Clausidium chelatum sp. nov.

(Figs. 3-4)

This species closely resembles *C. travancorense* sp. nov. and in the following description the major differences alone are indicated.

Female:

Body roughly oblong, about one and a half times as long as broad. Dorsal surface very minutely but closely spiny, the spines being more closely packed at the peripheral region. First thoracic segment with the cephalon half as long as the cephalothorax and its postero-lateral corners acutely produced. Segments two and three subequal, their postero-lateral angles rounded or obtuse, those of third more so. Dorsal plate narrower than the third peraeon segment and reaching the middle of the sixth peraeon segment. Sixth peraeon segment twice as broad as long. Abdomen with a pair of rudimentary appendages. Caudal rami elongate triangular, each with one outer and four apical setae.

Antennae, mandible, maxillae and maxillipeds as in *C. travancorense* but the bifid apical spine of second maxilla without barbs. Legs as in *C. travancorense* but the blade like process of first leg different, its proximal third narrow and abruptly widening further on. Distal segment of exopod of fourth leg with only four inner setae and the distal segment of fifth leg very broad, basal width more than half the total length.

Male:

Body similar to that of female, but the anteromedian part slightly sinuous, with a conspicuous horse-shoe shaped thickening. Cephalon and first peraeon segment together equal to half the length of the cephalothorax. Second peraeon segment longer than third. Dorsal plate very short. Sixth segment rectangular, three times as broad as long. Abdomen two segmented, caudal rami with one outer and four apical setae.

First antenna as in female, second antenna modified, third and fourth segments partially fused, former with two long slender setae and two short but stout apically blunt processes, fourth segment with a very stout process and five setae, one of the setae very stout. Mandible and maxillae as in female. Maxilliped modified into a subchela. The basal segment or ' palm ' short, with the inner corner produced

into a conical process or ' thumb '. Mobile process or ' finger ' long, apically curved and trifid. Both thumb and finger with a row of strong cusps. At the base of the finger is an apically bifid process and at the base of the thumb two lobed crests.

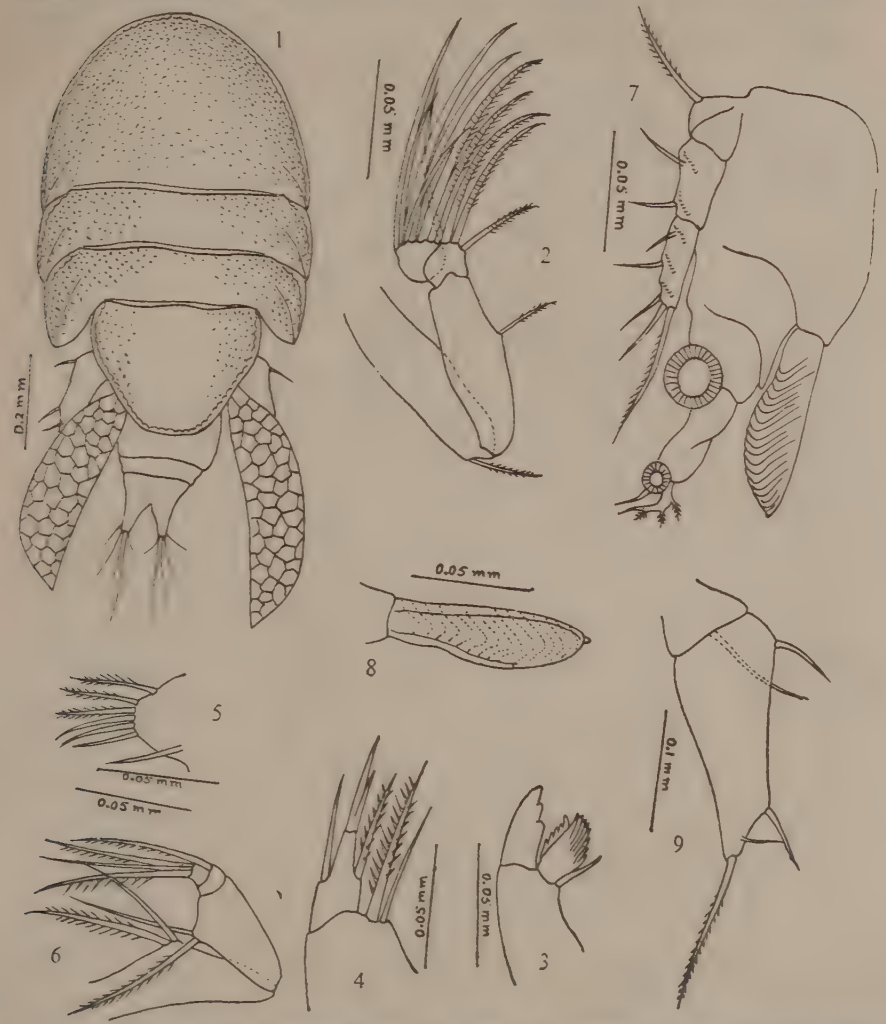

FIG. 3. *Clausidium chelatum* sp. nov. 1, female. 2, antenna. 3, mandible. 4, second maxilla. 5, first maxilla. 6, maxilliped. 7, first leg. 8, same, blade like seta. 9, fifth leg.

First leg narrower than in female, the stout seta of the endopod bent outwards. Fifth leg stout, its second segment four times as long as broad.

Length of female 1.1 mm., male 0.7 mm.

Material

Three males and two females from the gills of an unidentified species of *Callianassa* collected at Vizhingom.

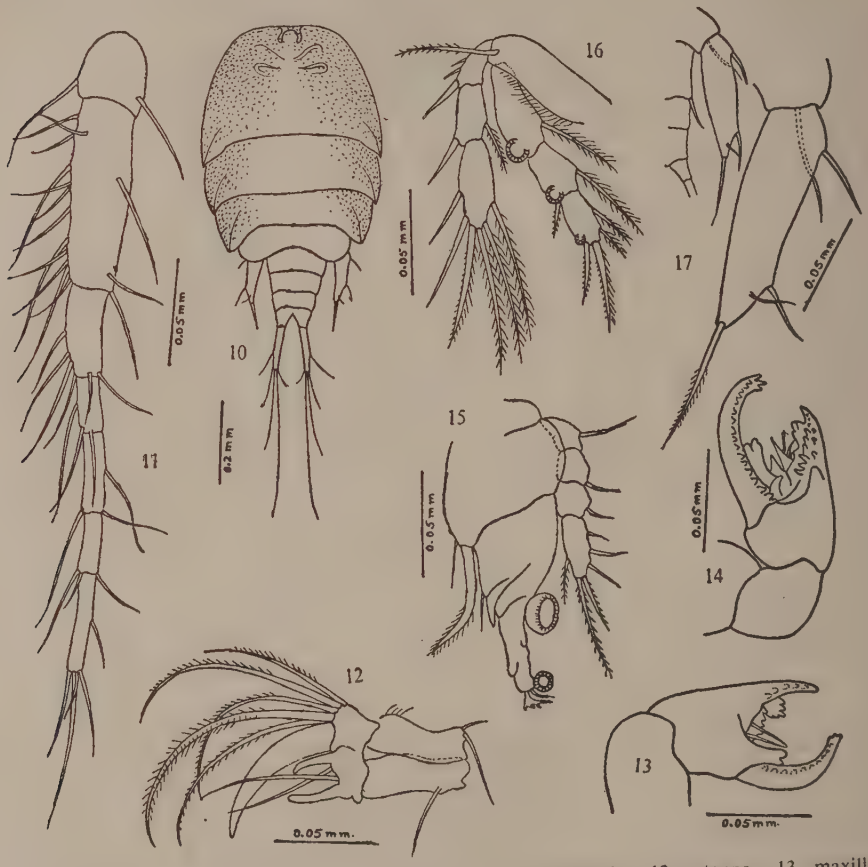

FIG. 4. *Clausidium chelatum* sp. nov. 10, male. 11, antennule. 12, antenna. 13, maxilliped, outer view. 14, same, inner view. 15, first leg. 16, fourth leg. 17, fifth leg.

Remarks

The female of *C. chelatum* differs from that of *C. travancorense* in the more spiny cephalothorax, narrower dorsal shield and the apically pointed ovisacs. The differences are more pronounced in the male. The maxilliped of *C. chelatum* is different from that of all the known species. In the presence of a bifid process at the base of

the finger it remotely resembles *C. dissimile* Wilson. In *C. chelatum* the third segment of second antenna of male has two stout processes and the fourth one. A near approach to this is seen in *C. senegalense* but in the latter species the third segment has only one process.

Acknowledgements

I am thankful to Dr. C. C. John. Professor of Marine Biology and Fisheries, University of Kerala, for helping me during the course of this study and also in the preparation of this paper. My thanks are also due to Shri K. R. Purushothaman Nair, S. N. College Marine Station, Quilon, who gave me specimens of the first species described above.

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J. Mar. biol. Ass. India, 1959, 1 (1): 65-68

PHYTOPLANKTON PHOTOSYNTHETIC PERIODICITY AS A FUNCTION OF LATITUDE

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The data, in which the daily periodicity in the ability of phytoplankton to photosynthesize under uniform conditions, found by Doty and Oguri (1957), were obtained within about 10° of the Equator. Yentsch and Ryther (1957), in confirming this periodicity, worked with phytoplankton from about 41° North Latitude. The former authors found, in general, a five- to six-fold variation between the values attained, while the latter found only a two-fold variation.

At the Productivity Symposium convened at Bergen, Norway, in conjunction with the 1957 annual meeting of the International Council for the Exploration of the Sea, various reports of this rhythm were made : from freshwater lakes by W. Ohle and W. Rodhe, and from marine waters by Robert Holmes and E. Steemann-Nielsen. The reports on marine waters were of as much as twelve-fold in one experiment near the Equator to a 20 per cent variation at about 56° N. Lat.

Grim Berge, working in the Norwegian Sea, seemingly obtained no periodicity ; however, his work was not designed to reveal one. Recently, Shimada (1958) has reported a range of about 2 to 3 from 18° N. Some of our results from Indonesian waters,[1] 5° S. to 4° N. Lat., average out to about a ten-fold variation.

The author is not aware of any report of such a periodicity in the photosynthesizing ability of algae raised under constant illumination as algae are usually raised in culture. After many generations, and often years of growth, under uniform conditions it would be surprising if a photosynthetic rhythm were to be found. On the other hand in a tropical marine phytoplankton crop growing under natural conditions (Verduin, 1957),[2] a pulsing by regular day-length light variations is experienced. Such conditions would be most favourable for the establishment of such a rhythm in photosynthesis, as Doty and Oguri (*l.c.*) reported. Hypothetically, it seems likely that at much higher latitudes such a phenomenon would be less pronounced or absent, for the populations[3] are exposed to extended periods of continuous darkness or light with rapidly changing lengths of intergrading day and night between times. At intermediate latitudes exposure would be to different day lengths with differing time of year. Again, as the Equator is approached the shortening of the twilight period and the lessening of variation in day length would result in the most pronounced pulsing effect. Since the Bergen meetings, the experimental establish-

[1] The present work was made possible through use of funds provided largely by research contracts with the U.S. Atomic Energy Commission, Contract AT-(04-3)-15, the U.S. National Science Foundation, Contract NSF-G3833, and funds from the Graduate Research Committee of the University of Hawaii.

[2] Verduin records a similar variation in the photosynthesis-respiration activities of freshwater phytoplankton.

[3] R. W. Holmes tells us (personal communication : 26-VI-1958) there are virtually no populations, e.g., in the Labrador Sea in Winter.

ment of rhythms in cells of algae, as reviewed by Tamiya (1957), has been brought to our attention. This lends further support to our explanation of the present phenomenon in nature.

In the course of defining this problem and setting up an hypothesis which could be tested experimentally, a plot of the factor (daily variation factor) resulting from the maximum rate for the day divided by the minimum rate obtained for the day was plotted (Fig. 1) as a function of latitude. The data at hand for this are too few and variable in nature to provide more than a very low level of confidence in any uniform treatment of them. Thus, in our present data, the apparent regression of

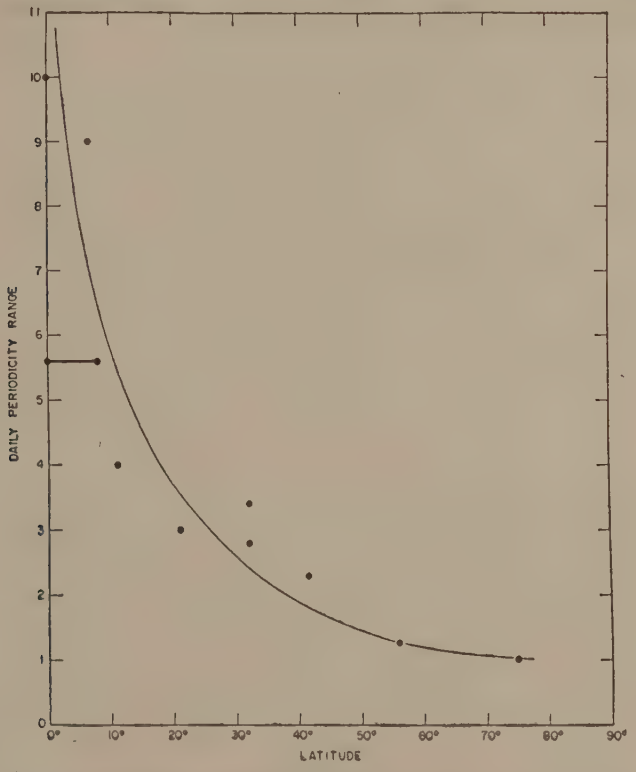

Fig. 1. Maximum photosynthetic rate for the day divided by minimum photosynthetic rate for the day as determined by uptake of carbon-fourteen plotted as a function of latitude. The curve was placed by inspection only.

the daily variation factor on latitude can only serve as a working hypothesis. The curve drawn among the plotted data points in the figure, represents this hypothetical relationship. This work is being extended to incorporate additional data collected to test this hypothesis further.

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J. Mar. biol. Ass. India, 1959, **1** (1) : 69-76

ON THE MORPHOLOGY OF THE GAMETOPHYTIC GENERATION OF *PADINA GYMNOSPORA* (KUETZ.) VICKERS

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Introduction

The genus *Padina* has about a score of species of which *P. gymnospora* (Kuetz.) Vickers alone is known to have a discontinuous distribution, occurring on the one hand in the West Indies, and on the other in Mauritius and India (Kuetzing, 1859 ; Vickers, 1905, 1908 ; Boergesen, 1914, '30, '37, '41, '48 ; Taylor, 1942, '43). In both the regions the gametophytes of this species appear to be rare. Two oogonial specimens which were in the Berlin Botanical Museum were studied by Kniep (1928, pp. 178-85), but details were not given about their morphology and place of origin. The writer collected four oogonial and two antheridial plants 12.8 km. west of Mandapam, at Puthumadam in the Gulf of Manaar, where they were obtained from shore-seine fishing nets which contained large numbers of tetrasporic plants as well. An oogonial plant and a few tetrasporic plants were dredged from a depth of 5.5 m. at 1.5 km. east of the place and 90 m. off-shore. An oogonial plant was found growing with numerous tetrasporic plants of the species, on Galaxea Reef (Krusadi I.), at a depth of 0.6 m. during low tide and another was found cast up at Pamban ; four oogonial plants were collected from a depth of 1.2 m. at low tide from Mandapam Camp (Palk Bay).

The antheridial plant, collected on 6th January, '53 which was the 6th day after full moon (*vide* Swamikannu, 1923), showed antheridia with sperm mother-cells at the early stage. The antheridial plant obtained on 29th January, '53 which was, full moon day showed mature sperm mother-cells. The three oogonial plants collected on the 5th and 6th (2 plants) days after new moon and the two oogonial plants collected on the 7th and 9th days after full moon showed immature oogonia. The oogonial plant collected on full moon day and the four collected on the 1st day after full moon showed mature oogonia. That the oogonia and the antheridia mature simultaneously at full moon and new moon is probable from the present specimens. In the allied genus *Dictyota*, Williams (1904 b, p. 183) found that the oogonia and antheridia are produced in fortnightly crops which begin to develop at the lowest neap tide and mature at the following highest spring tide, the gametes being liberated in the next few days.

The male gametophyte of *P. gymnospora* (Kuetz.) Vick. has not been reported before, and the two examples in the present sequence as also a male plant from Mombasa, Kenya, found in the Herbarium of the New York Botanical Garden, bearing the legend '*ex* herb. Hauck No. 38', which was determined by the writer, are therefore of interest. These collections definitely show that this species has a gametophytic generation with unisexual plants and that *P. australis* Hauck in which the gametophytic plant is bisexual (unpublished) is distinct from it though synonymised with it by Boergesen (1930).

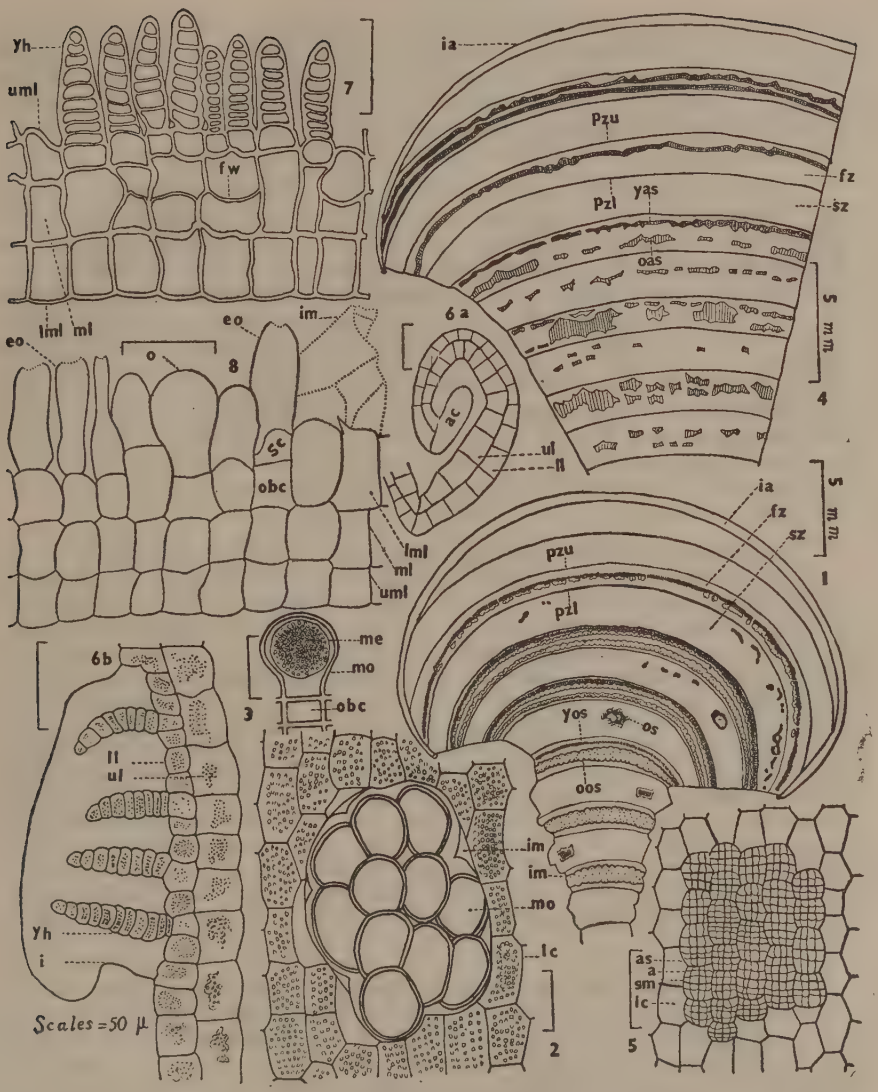
General Morphology

In the Mandapam area, the tetrasporic plants are usually larger than the oogonial and antheridial plants. All of them have the greater part of the frond made up of three layers of cells, *i.e.*, from about 1 to 2 cm. behind the involute apical border to the base of the frond, which is in general agreement with the description given by Boergesen (*l.c.*, p. 171) ; the involute part behind the row of apical cells, and the very young part of the spread-out region down to 1-2 cm. from the involute part have only two cell layers. The inferior part of the stipe of the plant in some individuals is formed by the complanate juvenile stage called *der Flachtrieb* by Reinke (1878, p. 16, pl. 3, Figs. 1-4), in which case the cross section of this region shows in one and the same section 6 layers in the median part and 3 or 4 layers at both ends of the section. Hauck (1887, p. 41) says the region of the stipe, in the genus, may be formed by the earlier terete juvenile stage (*der Rundtrieb*) in consequence of which the region would show more cell layers than the frond proper (*der Breittrieb*). In this species, as found here, the cells of the uppermost layer of the frond and those of the middle layer are on the average longer than those of the lowermost of the three layers.

The width of the fertile zones of the frond is slightly to distinctly less than that of the sterile zones, and the two types of zones alternate, which is as figured by Boergesen (1914, Fig. 30). However, sori often develop in the broader zones in addition to being present in the narrower zones. In the three phases of the species as growing in our area, the lower surface of the frond which unlike the upper is not coated with a film of lime bears the sori ; but in addition, a weaker development of sori on the upper surface may often be seen in the tetrasporangial and antheridial plants, though not commonly in the oogonial. The oogonial plant may be distinguished from the tetrasporangial chiefly by the sorus in the former being more compact and narrower than in the latter. The oogonial sori vary in width from 0.2 to 0.9 mm. and the tetrasporangial from 0.5 to 1.5 mm. Further the oogonial sorus is indusiate but not the tetrasporangial. The indusium of the oogonial sorus is the external layer of the outer walls of the oogonia which gets separated and raised up as the sorus matures, forming a thin dome over it. As the oogonia enlarge the indusium gets torn away and only its margin persists as a white cuticle around the fairly mature or empty sori as the case may be (Figs. 1, 2, 8, 10, 11). The diameter of the mature oogonia, 60-70 μ, is much less than that of mature tetrasporangia 90-125 μ. In the antheridial plant also the sori are compact and have about the same width as those of the oogonial plant, but an indusium over the antheridial sorus is rarely seen in the present material. Meiosis in the tetrasporangium has been shown to occur in *P. pavonia* (L.) Gaillon by Williams (1904 *a*), Georgevitch (1918 *a*) and Carter (1927).

Oogonial Plants

The oogonial plants vary from 4 to 11 cm., in height, from the holdfast to the apex, the expanse being rather more than the height. The basal part of the plant is stupose on both surfaces. Both the surfaces have alternately wider and slightly narrower zonation, the former being 1.5 to 3.0 mm. wide. The upper surface is thinly coated with lime. In the younger regions of the frond the broad zones tend to be sterile but the narrower are fertile (Fig. 1). In the older regions both the types of zones may be fertile, the sori developing later and to a less degree in the broad zones. The inferior line of the narrower zones is formed by a piliferous band



FIGS. 1-8. *Padina gymnospora* (Kuetz.) Vickers

1. Lower surface of oogonial plant. 2. Surface view of mature oogonial sorus. 3. Mature oogonium from sagittal section of frond. 4. Lower surface of antheridial plant. 5. Surface view of antheridial sorus. 6*a*. Sagittal section of apex of frond. 6*b*. Sagittal section showing piliferous band on the outside of the involute apex. 7. T. S. frond with piliferous band on upper surface. 8. T. S. frond showing oogonial stages.

a-antheridium. *ac*-apical cell. *as*-antheridial sorus. *eo*-empty oogonium. *fw*-frontal wall. *fz*-fertile zone. *i*-indusium. *ia*-involute apex. *im*-indusial margin. *lc*-lower-surface cell. *ll*-lower layer. *lml*-lowermost layer. *me*-mature egg. *ml*-middle layer. *mo*-mature oogonium. *o*-oogonium. *oas*-old antheridial sorus. *obc*-oogonial basal cell. *oos*-old oogonial sorus. *os*-oogonial sorus. *pzl*-piliferous zone on lower surface. *pzu*-piliferous zone on upper surface. *sc*-subsidiary cell. *sm*-sperm mother-cell. *sz*-sterile zone. *ul*-upper layer. *uml*-uppermost layer. *yas*-young antheridial sorus. *yos*-young oogonial sorus. *yh*-young hair.

on the lower surface of the frond, and the superior by one on the upper surface, and in the case of the broad zones it is the opposite. Boergesen (1930, p. 171) observed that in this species the piliferous bands are placed alternately on the upper and lower surfaces, but it has to be indicated that he had taken the upper surface to be the lower and *vice versa*, a confusion which appears to have arisen from Hauck's statement (*l.c.*) that chiefly the upper surface bears the sori, in the genus.

In the upwardly rolled margin, there is at the very edge a single layer of apical cells. Immediately behind them the frond is two layered and remains thus in the various turns of the rolled up part (Fig. 6*a*). At first the two cell layers are of equal depth, later the inner (upper) becomes deeper than the outer (lower). On the outer layer there are one or two piliferous bands (Fig. 6*b*), the hairs dropping off as the rolled up apex unfurls, but later new hairs are formed from the same initials. The piliferous bands of the upper surface arise anew some distance below the rolled up margin (Figs. 7 and 12*a*). Bitter (1899, p. 22) has proved that the hairs develop in reaction to strong light. When the rudimentary hairs grow out into long monosiphonous hairs, a peculiarity is noticed in the Mandapam plants, namely that new walls are laid down inside the old walls of the cells of the rudimentary hairs, and while the new walls of each segment elongate, its old walls remain at the base of the segment and are seen usually as two minute spikes, one at either end of each transverse septum or at times as a complete collar (Fig. 12*b*).

The depth of the cells of the upper layer, in the 2-layered region of the frond, below the involute apex, is 35.0-59.5 μ, of the lower layer 24.5-38.5 μ; the width of the cells of both the layers, 17.5-24.5 μ. The cells of the upper layer are longer on the average than those of the lower, their length varying between 28-84 μ (usually 35-70 μ) and between 17.5-59.5 μ (usually 28-42 μ) respectively. From about 1-2 cm. below the involute apex to the basal part, excluding juvenile stages that may be present at the base, there are 3 cell layers ; this increase to three layers results from the periclinal (frontal) division of the upper of the original two layers (Figs. 7 and 11). In the middle part of the frond the depth of the two upper layers is about 26.3 μ each, of the lowermost layer, generally 35.0 μ, but in the basal part all three layers are usually equal in depth, each layer being about 35.0 μ in depth. Both in the middle and basal parts of the frond the width of the cells of all three layers is equal, varying from 21-28 μ, the cells appearing in tiers in transverse sections of the frond (Figs. 7 to 9 and 13). The length-range of the cells of the two upper layers is greater than that of those of the lowermost layer (Fig. 10), the former 35-70 μ, the latter 17.5-42.0 μ with the majority being 35.0 μ long in the case of the lowermost layer.

The oogonial sori are borne almost exclusively on the lower surface in our specimens, and the young sorus is a continuous or an interrupted band, 120-422 μ wide, with jagged margins. There may be one to three bands of sori in a zone which are formed successively towards the apical margin (Fig. 1), or a young band is seen on either side of an old band. The oogonial mother-cells develop from superficial cells by increase in height (Fig. 9), and when it is between 49 and 52 μ a cell is cut off at the base of each mother-cell, the upper cell developing into the oogonium (Fig. 10). The mature oogonium is like an inverted sphaerical flask about 60 to 70 μ in diameter, the neck being very short (Fig. 3). The basal cell of the oogonium is in length, 25-35 μ, in height and width, 21-28 μ. The indusium becomes visible, in surface view and sections of the frond, when the sori are fairly

mature (Figs. 2, 10, 11). After liberation of the eggs the empty oogonia are seen, in sections of the frond, as vertical, sub-cylindrical cells, open at the top, 52-70 μ by about 35 μ, and densely arranged, with at times a few intervening cells (Fig. 11, *uom*). The basal cell, in rare instances (Figs. 8 and 10), divides, cutting off a cell towards the periphery which is known as the subsidiary cell. Such divisions of the basal cells have been described as occurring in *P. pavonia* (L.) Gaillon, the upper halves developing into secondary oogonia (Reinke, *l.c.*, Georgevitch, 1918, *b*).

Whereas fertilization and germination in the genus normally occur after the eggs are shed, germination *in situ* was seen in some of the present plants. Wolfe (1918, pp. 88-89) found in *P. vickersiae* Hoyt that the eggs may at times be fertilized before they are shed. He also found that eggs which remained unfertilized after having been shed occasionally showed parthenogenetic development but failed to grow into mature plants. Vegetative reproduction by propagula that develop terminally or laterally on mature hairs of the piliferous zones of the frond was noticed in one of the present oogonial plants. Küster (1899, p. 159) describes propagula arising on rhizoid-like filaments growing on the lower surface of the frond in *P. pavonia* (L.) Gaillon.

Antheridial Plant

The antheridial plant (C.M.F.R.S. Herbarium No. 1013) is 14 cm. in height from the holdfast to the apex, and 16 cm. in expanse. It is deeply divided into cuneate lobes and is to a good extent incrusted by a *Corallinaceae*. The wider zones on the two surfaces of the frond are 1.5 to 2.5 mm., and they alternate with slightly narrower zones (Fig. 4). The lower surface has far more extensive sori than the upper. On the lower surface, in some of the younger parts, there is an alternation of fertile narrow, and sterile broad zones; but for the most part, adjoining zones of both types are fertile. On the upper surface the relatively weak development of sori is seen both in the narrower and broad zones. The frond is 2-layered for about 1 cm. below the up-curled apical part, and the rest of the frond downwards 3-layered. In the arrangement of the piliferous bands, cell-size in the three layers, and mode of development of the frond from the row of apical cells, there is agreement with the oogonial plants described above.

The sori are raised a little above the surface of the frond and form continuous or interrupted bands, 100 to 350 μ wide, the margins of the bands being jagged. The bands of sori arise successively in a zone; thus young and also empty sori may be seen side by side. The antheridia are oblong or square in surface view of the frond and are arranged in close, longitudinal rows (Fig. 5). In the case of the lower surface of the frond, the longer cells of the area forming a sorus divide by a transverse wall into two antheridial mother-cells, thus the range in length of the antheridial mother-cells is 17.5-28.0 μ, whereas that of the lower surface cells is 21-42 μ. When a sorus is formed on the upper surface of the frond the longer cells divide by 1 to 3 transverse walls forming 2 to 4 antheridial mother-cells, evidence of this being seen in old sori after the antheridia have disappeared (Fig. 16, *tw*). The width of the superficial cells forming the antheridial mother-cells remains the same normally, but exceptionally there is a division by a sagittal wall (Fig. 13, *ns*). The antheridial mother-cells develop from the superficial cells by increase in height. In each mother-cell a periclinal (frontal) wall then cuts off a low basal cell having the same width and length as the mother-cell. In height the antheridia are

FIGS. 9-16. *Padina gymnospora* (Kuetzing) Vickers

9. T. S. frond with oogonial mother-cells. 10. Sagittal section frond showing oogonial sorus and portion of empty adjoining sorus on either side. 11. Sagittal section frond with oogonial sorus. 12*a*. Uppermost layer of frond in sagittal section with young piliferous band. 12*b*. Proliferation at base of segment of hair, of piliferous band. 13. T. S. frond showing antheridial sorus. 14. Sagittal section frond with antheridial sorus on upper and empty antheridial sorus on lower surface. 15. Sagittal section frond showing indusium over empty antheridial sorus. 16. Upper-surface cells of frond showing 2 or 4 basal cells after break-down of antheridia.

a-antheridium. *abc*-antheridial basal cell. *eas*-empty antheridial sorus. *eos*-empty oogonial sorus. *eo*-empty oogonium. *fw*-frontal wall. *i*-indusium. *im*-indusial margin. *ll*-lower layer. *lml*-lowermost layer. *ml*-middle layer. *ns*-new sagittal wall. *nw*-new wall. *o*-oogonium. *obc*-oogonial basal cell. *om*-oogonial mother-cell. *ow*-old wall. *sc*-subsidiary cell. *sw*-sagittal wall. *tw*-transverse wall. *ul*-upper layer. *uml*-uppermost layer. *uom*-undeveloped oogonial mother-cell. *yh*-young hair.

one and a half to twice their width, the height 17.5-35.0 μ, width 12.0-24.5 μ. The height of the basal cells is 10.5-17.5 μ. The antheridia of the lower surface are mostly shorter than those of the upper surface, though the length-range is the same. The antheridial sori do not show the presence of an indusium usually (Figs. 13 and 14), but in exceptional cases an indusium is seen (Fig. 15, *i*). The sperms are liberated by the walls of the antheridia and sperm mother-cells dissolving. Subsequent to the liberation of the sperms the sori appear as depressed areas on the frond, as the height of the basal cells is less than that of the general cells on either surface. The antheridium has in surface view of the frond, usually 16 to 32 sperm mother-cells with very delicate walls, 32 to 40 in transverse and sagittal sections ; thus there are about 128 to 320 sperm mother-cells in an antheridium. It is probable as has been demonstrated by Williams (1897, pp. 547, 548 and 552) in allied genera that the sperms of *Padina* are produced singly in the sperm mother-cells and are motile.

The following specimens are preserved in the Herbarium of the Central Marine Fisheries Research Station, Mandapam Camp : Puthumadam—No. 501, 31-1-1952, Oog. No. 1012, 6-1-'53, Anth. (piece only). No. 1013, 29-1-'53, Anth. No. 1014, 29-1-'53, Oog. No. 3212, 29-10-'57, Oog. (piece only). No. 3213, 29-10-'57, Oog. Krusadi I : No. 3214, 14-11-'57, Oog. Pamban Town : No. 3215, 16-11-'57, Oog. Mandapam Camp (Palk Bay) : No. 8001 (4 plants), 24-4-'59, Oog.

Acknowledgements

The writer is grateful to Drs. N. Kesava Panikkar and S. Jones for helpful criticism, and to Prof. W. R. Taylor for highly valuable suggestions.

Summary

The gametophytes of *Padina gymnospora* (Kuetzing) Vickers are far from well known. It was possible to obtain ten oogonial and two antheridial plants in the Mandapam area. The antheridial plant is being reported for the first time. The frond structure in the two phases of the gametophytic generation of this species is found to agree with that of the sporophyte. A peculiarity in the structure of the hairs in the species, noticed in the present material, has been described. Germination *in situ* was seen, and a few oogonial sori were found to show the presence of the subsidiary cell. A few of the hairs of the piliferous bands of the frond, in one case, were seen to give rise to a propagule which was terminally or laterally placed on the hair. The evidence that the gametophytic generation of *P. gymnospora* (Kuetzing) Vickers has unisexual plants proves that it is distinct from *P. australis* Hauck, a species having a bisexual gametophyte, which was synonymised with it. Observations indicate the existence of periodicity in the development of gametes in *P. gymnospora* (Kuetzing) Vickers.

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J. Mar. biol. Ass. India, 1959, **1** (1) : 77-84

A NOTE ON THE BREEDING OF COPEPODS AND ITS RELATION TO DIATOM CYCLE[1]

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Introduction

During the last fifty years a considerable amount of work has been done on the copepods of the Indian waters but these investigations deal mainly with the taxonomy and seasonal variations in their abundance and our knowledge of the biology of these is very meagre. Because the copepods play an important rôle in the economy of the sea, detailed work on the biology of the common copepods was taken up in the Central Marine Fisheries Research Station and the present observations relate to the breeding of copepods in general and its relation to the diatom cycle. The observations are based on regular samples collected from the inshore waters of the Gulf of Mannar and Palk Bay off Mandapam.

The authors record their thanks to Dr. S. Jones, Chief Research Officer, Central Marine Fisheries Research Station, for going through the manuscript and offering valuable suggestions.

Breeding of Copepods

The occurrence and abundance of nauplii and copepodites (Figs. 1-3) have been taken as an indication of the breeding time and intensity. This procedure was necessitated in view of the practical difficulties in estimating the number of eggs particularly in those species of copepods which do not carry egg-sacs. In considering the breeding of copepods as a whole, it is found that one species or another is breeding throughout the year in varying intensities. But it is equally obvious that there are distinct peak periods.

In Palk Bay breeding seems to take place almost throughout the year but the intensity extends from the second half of April or early May up to October. During this period a series of peaks are noticed in the distribution of nauplii, the peaks occurring almost at intervals of one month. This is obviously indicative of the production of successive broods during the season. The sampling is, however, not adequate to give any information about the number of broods as the copepods pass through the nauplius stage rapidly. In the temperate waters the usual number of broods is three or four and in cold waters this appears to be reduced to one. It is not unlikely that in the tropical waters there are more number of broods than in the temperate and cold waters. In the Gulf of Mannar also breeding takes place

[1] Published with the permission of the Chief Research Officer, Central Marine Fisheries Research Station, Mandapam Camp.

throughout the year but the pattern seems to be different from that of Palk Bay. Breeding intensity is often at its lowest between May and August when it is at a peak in Palk Bay, and highest during September to March or April. The data available suggest that the intensity of breeding on the whole is lower in the Gulf than in Palk Bay.

It was pointed out by Prasad (1956) that in the Gulf of Mannar during the years 1951-53 the average annual standing crop of copepods is higher compared to that of Palk Bay. This was found to be the case during the year 1953-54 also by Kartha (1959). But surprisingly enough the nauplii population appeared to be distinctly higher in Palk Bay in all these years, except in 1952 when the level of populations was somewhat similar in the two regions. It will therefore be of interest to examine more closely the relative abundance and distribution of copepodites and adults in the two areas in order to ascertain whether the difference noticed in the nauplii populations is real or artificial. Kartha (*l.c.*) has already reported that the distribution of copepodites and the adults in the two areas showed differences not only in abundance but also in species composition. Considering the average annual population of copepodities it can be said that during the period of observation it was higher in Palk Bay except in 1952 when it was the other way about. However, the magnitude of differences in the population levels, as between nauplii on the one hand and copepodites on the other, is less evident in the case of copepodites. In the Gulf, there is distinctly a greater population of copepodites during September to March, whereas in Palk Bay their maximum is during May to September. Comparing the adult population of copepods in the two areas the margin of disparity is still further reduced and it is only during January to March that there is a remarkably higher population in the Gulf, which mainly accounts for the higher average annual population. During January-February a large-scale migration of copepods from Palk Bay, where the sea is turbulent and the phytoplankton production is at an extremely low level, to the Gulf of Mannar where conditions are highly favourable, seems possible. Such movements may also be facilitated by the fact that during this period the drift of water is from Palk Bay into the Gulf. In both areas the adults increase in their number by November but in Palk Bay there is an abrupt decimation in the adult population by about the end of December or early January and the corresponding sudden increase of adults in the Gulf. This is strongly suggestive of the migration from one place to another owing to unfavourable conditions. Detailed study of the adult populations on the basis of measurements of the cephalothorax is in progress in the hope that it will throw some light on this aspect.

It is well known that the productive potential or rate of fecundity and breeding time varies from species to species. Kartha (*l.c.*) in his detailed study on the adult copepods of these areas reported that in the Gulf of Mannar there is a higher population of *Paracalanus parvus*, *Acrocalanus* spp., *Corycaeus* spp., and *Oithona* spp. An examination of the occurrence of these different species indicates that during January-February there is a very large population of *P. parvus* ; *Acrocalanus* spp. are abundant during the second half of the year ; *Corycaeus* spp. have peaks in March and September-November and *Oithona* spp. are at their maximum in September. In January several specimens of *Pseudodiaptomus mertoni* also are seen carrying eggs. It was mentioned earlier that in the Gulf of Mannar copepodites are present throughout the year but are more abundant during the months of September to March (Fig. 3) which clearly indicates the greater intensity of breeding during this period. The species commonly occurring during these months have been listed above and

all of them are known to have relatively small nauplii ; their size ranging from 68 to 180 μ. The question therefore arises whether in the event of the above-mentioned species breeding, their nauplii are adequately represented in the net plankton collections. The meshes of the net used are *ca.* 230 μ and it is obvious that a large percentage of these small nauplii would have escaped through the meshes. Thus, the low population of nauplii observed in the Gulf is purely artificial caused by inadequate sampling. This is further substantiated by the data on the nauplii of the same area collected recently during the investigations on the primary production of the area, by filtering through filter paper or centrifuging known quantities of water. These data also indicate that nauplii are more abundant during September to March. Several other factors undoubtedly influence the level of population of nauplii. One such factor may be the rate of mortality. The breeding of copepods in the Gulf, from September to March, coincides well with the spawning of fishes of this area, whereas there appears to be very little spawning of fishes, as judged from the occurrence of fish eggs and larvae in the plankton, in the inshore waters of this area during April or May to August when there is active breeding of copepods in Palk Bay. The main peak of spawning of fishes in both the areas is in February-March and a secondary one during September-November and Bapat (1955) has reported that there is a greater concentration of pelagic fish eggs in the Gulf of Mannar than in Palk Bay. During both these periods there seems to be active breeding of copepods in the Gulf particularly of those species having small nauplii and consequently a large crop of minute nauplii are available for the fish larvae. It is well known that larval copepods form a most important source of food for some of the fish larvae and the feeding by a large number of fish larvae on the nauplii is bound to reduce their number appreciably.

In considering all these it appears that the difference in the intensity of nauplii population noticed between the two areas is more apparent than real and that intensive breeding of copepods does take place during September to March in the Gulf when most of the species spawning have relatively small nauplii, while in Palk Bay intensive breeding is noticed during May-September and the species then breeding mostly have relatively larger nauplii. Further, there is no indication to suggest that the same species is breeding at different times in the two regions. The breeding periodicities show a positive relation to the diatom cycles of these areas as will be discussed below.

Breeding and its Relation to Diatom Cycle

The connection between the phytoplankton maxima and breeding of copepods in the temperate and cold waters has been discussed by many workers. Considerable amount of information is available which indicates that there does exist a relation between the breeding of copepods and the presence of an abundant phytoplankton population. It has even been shown that in areas where there is only one diatom increase in the year, as in East Greenland, copepod reproduction was entirely dependent on the diatom increase (Ussing, 1938. See also Marshall and Orr, 1952 for other related references). As against this the investigations of Clarke and Zinn (1937) in the Woods Hole region did not indicate any necessary dependence of copepod production upon diatom abundance. Recent experiments on *Calanus finmarchicus* by Marshall and Orr (1952) to study the effect of food on egg production have revealed that food does not act as an immediate stimulus for the actual egg-

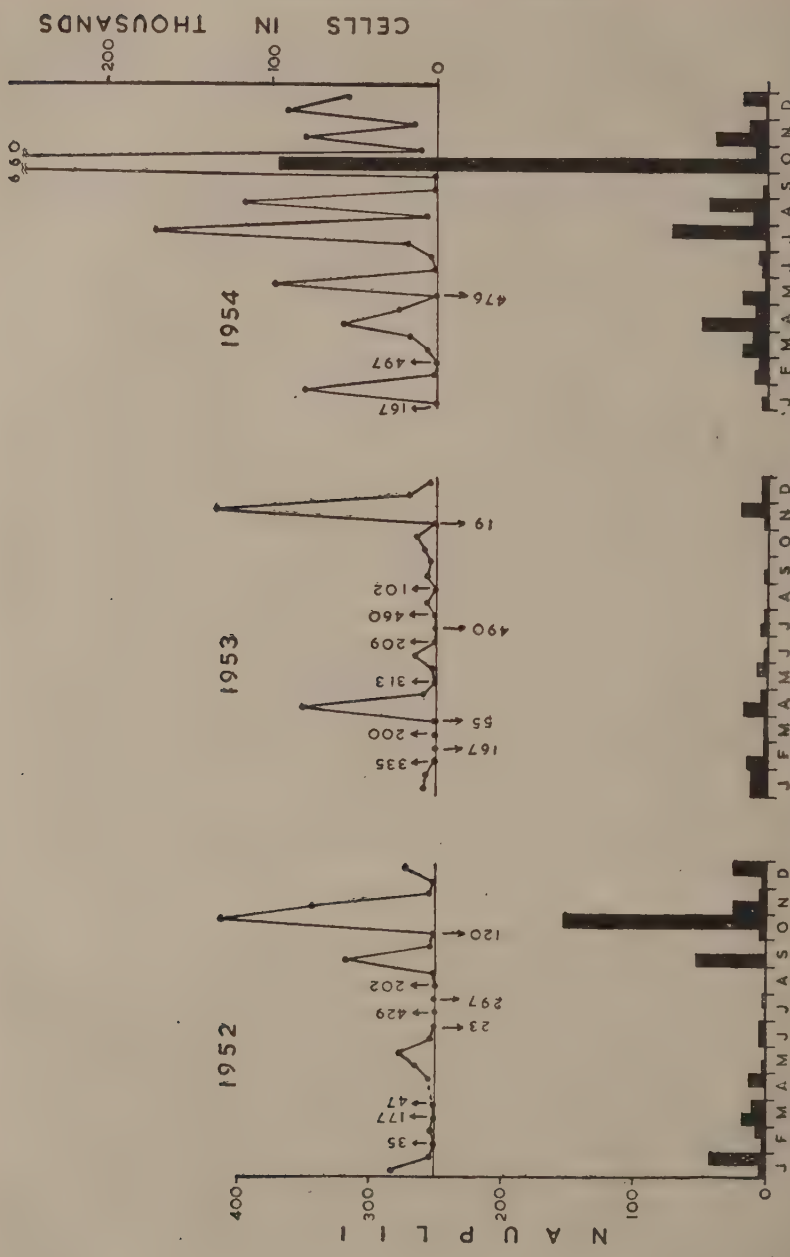

FIG. 1. The distribution of nauplii and the diatom cycle in the Gulf of Mannar.

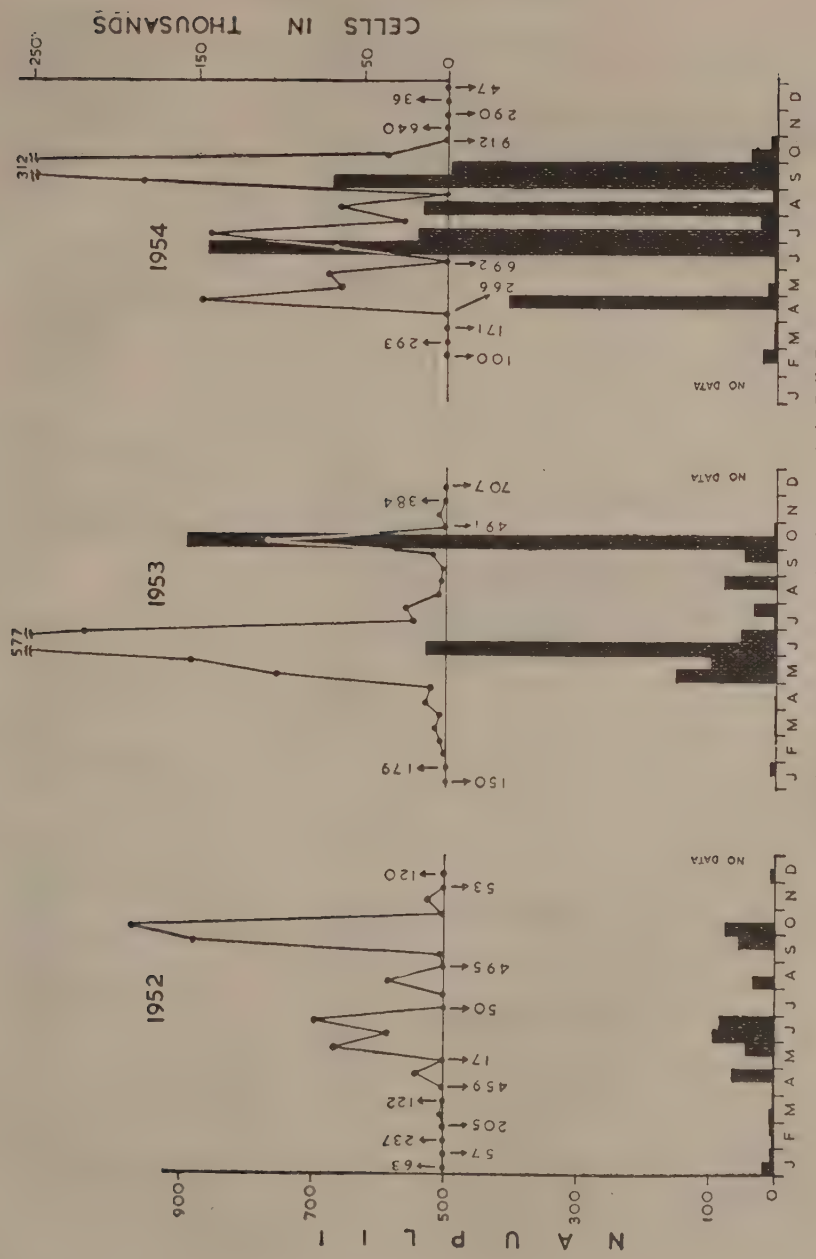

FIG. 2. The distribution of nauplii and the diatom cycle in Palk Bay.

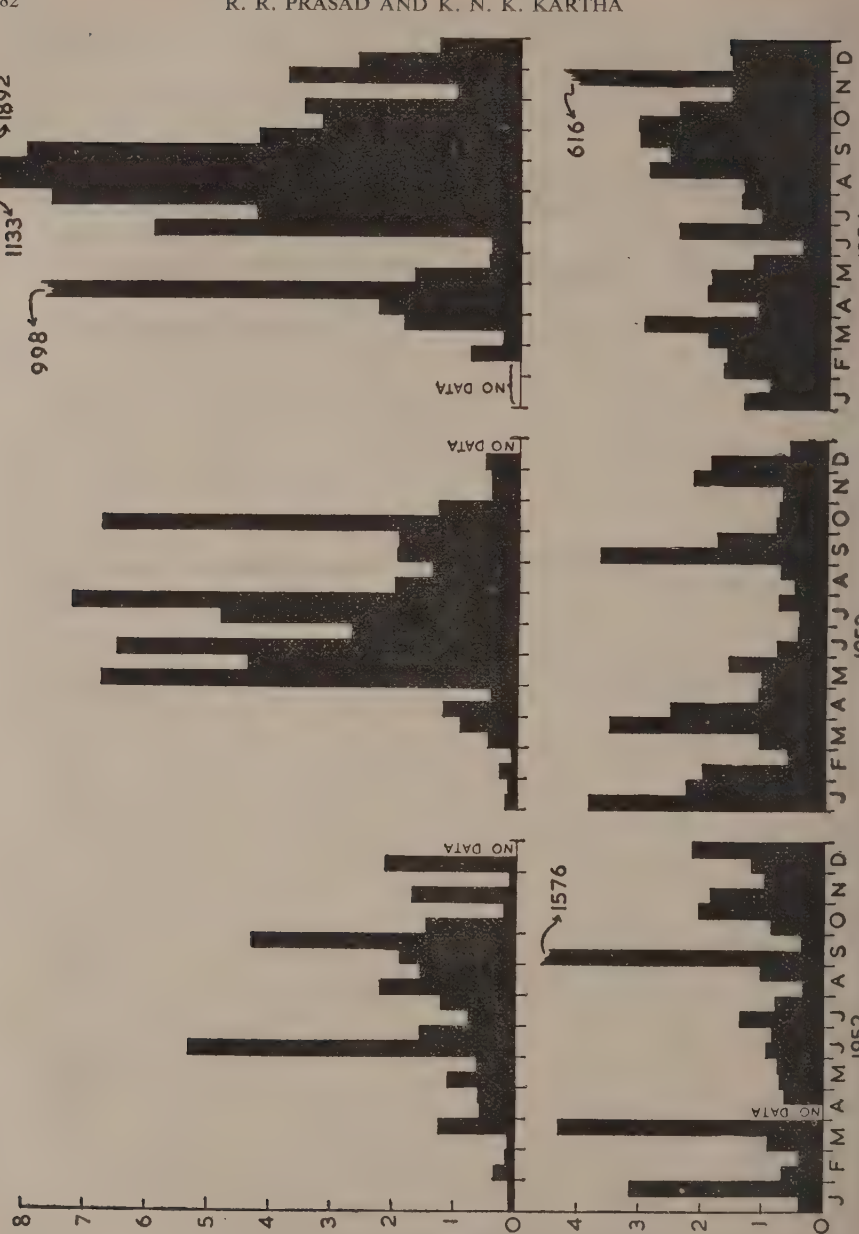

FIG. 3. The distribution of copepodites in the Gulf of Mannar (Lower half) and Palk Bay (Upper half).

laying, but when available it seems to be rapidly digested and used for egg production. A number of different cultures of diatoms and flagellates were tested as food and it was found that all the diatoms resulted in the production of eggs while all the flagellates were not successful. It was also observed that females though ready to lay eggs do not necessarily do so but may hold them up until conditions become favourable. They further remarked that the production of broods by some of the smaller copepods also seems to depend upon diatom outburst and it may therefore be expected that these will show a similar effect of feeding on egg-laying. It thus becomes evident that some factor or factors act as a trigger to set off egg laying and it has been suggested that this may explain why in the sea egg-laying often seems to coincide with diatom increase although food does not necessarily act as the immediate stimulus to egg-laying.

In the temperate waters because of the short duration of the phytoplankton abundance the spawning in many marine invertebrates coincides with the diatom increase. This synchrony has been noticed by several workers. Recently Barnes (1957) has remarked : '..... that in *many* boreo-arctic forms mechanisms exist which tend to synchronize larval development with the spring phytoplankton outburst ; and that this takes place not only at the northern limits of distribution but also over a wider range.' Recent investigations on the breeding of tropical marine invertebrates have strongly suggested that there are regular periodicities (Prasad, 1954) and although in the coastal areas phytoplankton may be available almost throughout the year in varying quantities, still there is reason to believe that the phytoplankton cycle has considerable influence on the breeding of many invertebrates. Barnes (1957) discussed the synchronization of the spring diatom outburst and naupliar development with particular reference to *Balanus balanoides* and demonstrated by experimental work the presence of a substance, presumed to be the resultant of the metabolic activity of the diatoms, that stimulates the release of nauplii.

Krishnaswamy (1950) in his study of the larval stages of some copepods of the Madras plankton states that ' the abundance of food due to diatom outbursts may be responsible for the abundance of larvae in July-September, December and March.' He noticed that the larvae were not common when diatoms reached their maximum concentration in April, May and June and remarked that the observations are in agreement with those of Clarke and Zinn (1937) according to whom the spawning periods of *Calanus* did not occur at times of diatom maxima. Ramamurthy (1953), on the other hand, observed in the same area that the peaks in the copepod nauplii were in April-May and November-December and these coincided with the diatom peaks. Further work seems to be necessary to explain this difference.

The present data indicate clearly the relation between the diatom maxima and the breeding of copepods (Figs. 1, 2 and 3). As mentioned earlier the maximum breeding of copepods in the Gulf of Mannar and Palk Bay shows differences in time. In the Gulf there is a comparatively higher diatom population during October to March and blooms of certain species of diatoms causing minor peaks are recorded during January-March and July-August. The two major peaks are, however, during September-October and May, the former being more prominent of the two. In Palk Bay there are only two peaks one in June and another in September and minor peaks are seldom noticed. In July-August the diatom population in Palk Bay is on an average higher than that of the Gulf of Mannar (Prasad, 1956 and 1958). From Figs. 1 to 3 it is evident that the

maximum breeding in the Gulf of Mannar is during September to March and in Palk Bay during May-September which coincides with the diatom abundance of these two areas. Further, in Figs. 1 and 2 the successive peaks of nauplii coincide with diatom peaks, but however, the converse is not always true. Detailed work on the breeding of particular species of copepods and its relation to specific phytoplankters will be interesting and such investigations are necessary to establish more precisely the nature of relationship.

Summary

The breeding of copepods in the Gulf of Mannar and Palk Bay has been discussed. The maximum breeding in the Gulf takes place during September-March, whereas in Palk Bay it is from May-September. The difference in the intensity of breeding at the two regions is more apparent than real and the possible reasons for the observed differences are discussed.

The species of copepods breeding during these periods at the two regions are different.

The close relation between breeding of copepods and the diatom cycles of the two regions is discussed and it is observed that in both the areas breeding, to a very large extent, is dependent on the diatom cycle.

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CHARACTERISTICS OF SEA WATER OFF MANDAPAM, 1950-1954[1]

By R. Viswanathan
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Introduction

The chemistry of sea water in Mandapam area has been described by Jayaraman (1954) on the basis of observations during 1950-1953. The data related to seasonal variations in salinity, dissolved oxygen and nutrient salts at two inshore stations in Gulf of Mannar and Palk Bay. The corresponding planktological characteristics were detailed by Prasad (1954 ; 1956) who also summarised the sequence of seasonal changes and indicated the factors governing the dynamics of phyto- and zoo-plankton populations.

In the present paper, data cited by Jayaraman and Prasad have been consolidated along with those obtained subsequently and analysed for trends by the method of moving averages. A preliminary examination indicated differences in the trends of dissolved oxygen and nutrient salts and prompted a study of the significance of these two variations in standing crop of phytoplankton.

Methods and Results

The procedure for the chemical determinations was the same as that described by Jayaraman. The plankton records were kindly placed at my disposal by Dr. R. R. Prasad to whom I wish to express my thanks. For facilitating handling of plankton data, the census figures, referring to the standardised subsample (Prasad, Bapat and Tampi, 1952) have been plotted logarithmically.

The trends in surface salinity, dissolved oxygen and phosphate and in phytoplankton are given in Figs. 1-4.

Salinity and dissolved oxygen were lower in Palk Bay than in Gulf of Mannar. A downward trend in salinity towards the end of 1952 was followed by similar decreases in oxygen towards the middle of 1953 and in phosphate towards the end of 1953. Differences were observed in the oxygen-phosphate relationship (Scatter diagrams. Figs. 5 and 6).[2] A general inverse relationship between phosphate and phytoplankton was noticed such as been reported in some coastal areas (vide Kalle, 1933). The range of fluctuation in phosphate in the Gulf of Mannar was more uniform than in Palk Bay. The standing crop of phytoplankton in the Gulf showed a tendency to increase, though the range of variation was higher in the Bay.

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[2] 1 microgram. at. P/L. = 30.98 mg. P/M^3. The scatter diagrams are similar to those described by Rochford (1951).

Discussion

From Figs. 3 and 4, it is seen that the patterns of variation in phosphate in the Gulf of Mannar and Palk Bay exhibit greater similarity than do the correspond-

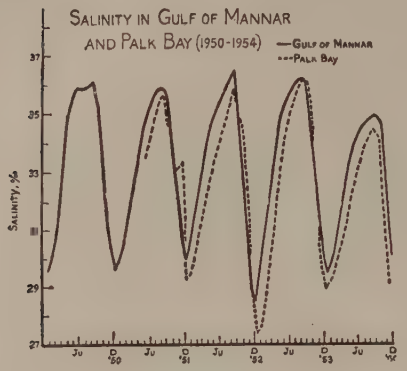

Fig. 1.

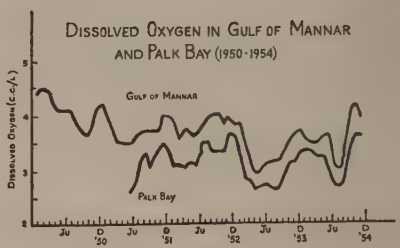

Fig. 2.

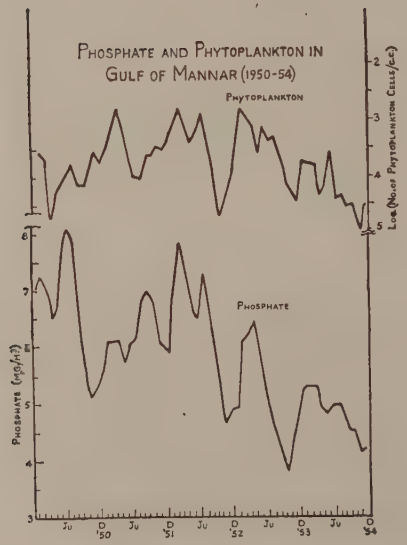

Fig. 3.

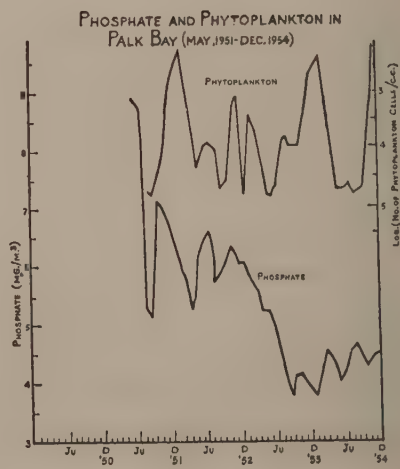

Fig. 4.

ing responses in the standing crop. Judging from the gradients of the phosphate and plankton curves at the points of maximum decrease and increase respectively in

each year (Fig. 7), it would appear that the increase in plankton per unit decrease in phosphate is the same at both the stations. The differing trends in standing crop are obviously due to dissimilar rates of replenishment of phosphate. The regeneration of phosphate in the Gulf is, in general, quicker, more uniform and extensive than in the Bay. A possible reason for this may be that, unlike the phytoplankton

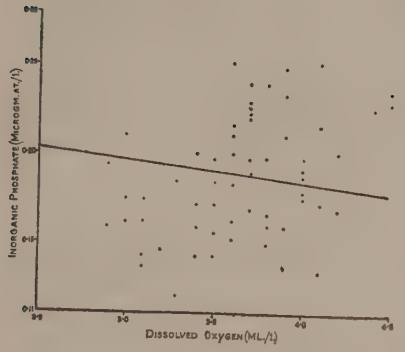

Fig. 5. Phosphate and dissolved Oxygen in the Gulf of Mannar.

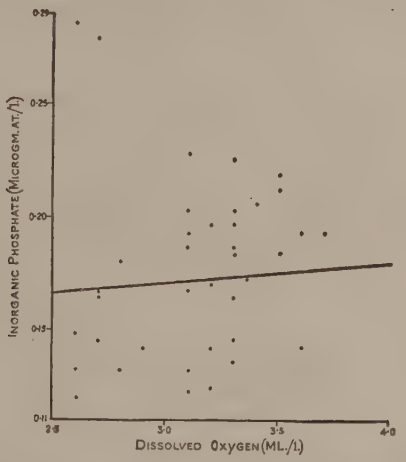

Fig. 6. Phosphate and dissolved Oxygen in the Palk Bay.

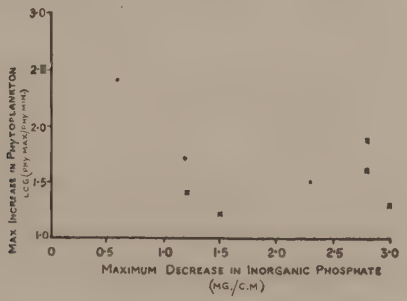

Fig. 7. Changes in phosphate and phytoplankton in the Gulf of Mannar (X) and Palk Bay (0).

minimum in the Gulf of Mannar, the corresponding minimum in Palk Bay coincides with the predominant northeast monsoon in this region. The adverse effects of turbulence on regeneration and utilisation of nutrients are hence likely to be more pronounced in the Bay.

The relationship between metabolic phosphate and oxygen, both in photosynthesis and in oxidation of organic matter, has been described by Redfield (1948). A variety of factors are admittedly involved in the reaction and a direct regression between inorganic phosphate and dissolved oxygen cannot possibly be expected (Rochford, 1951). Nevertheless, in view of the association observed in the present instance among the variations in oxygen, phosphate and phytoplankton, it would be of interest to study in greater detail the oxygen-phosphate relationship with reference to the standing crop of phytoplankton.

Summary

Some of the chemical and biological characteristics of sea water off Mandapam have been analyzed for trends.

Salinity and dissolved oxygen were lower in Palk Bay than in the Gulf of Mannar. Oxygen-phosphate relationship and likewise trends in phytoplankton were different ; it is considered likely that this association is of some significance.

Acknowledgements

My thanks are due to Dr. N. K. Panikkar for guidance and to Dr. R. R. Prasad for helpful discussions.

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MARINE BIOLOGICAL AND OCEANOGRAPHIC INSTITUTIONS OF THE WORLD

1. THE PLYMOUTH LABORATORY OF THE MARINE BIOLOGICAL ASSOCIATION OF THE U.K.

By F. S. Russell
Director, The Laboratory, Citadel Hill, Plymouth

The Marine Biological Association of the United Kingdom was founded in 1884 to promote accurate researches leading to the advancement of zoological and botanical science and to an increase in our knowledge of the food, life, conditions and habits of British fishes. The work of the Association is controlled by a council elected annually by its subscribing members.

The Plymouth laboratory was opened in June 1888, and since that date a new library and further laboratory accommodation have been added. The site was chosen on account of the rich and varied fauna and wide range of environments to be found in the immediate neighbourhood of Plymouth.

The Association is maintained by subscriptions and donations from private members, universities, scientific societies and other public bodies ; a generous annual grant has been made by the Fishmongers' Company since the Association began. From the beginning a Government grant in aid of the maintenance of the laboratory has been made. In recent years this grant has been greatly increased in view of the assistance which the Association has been able to render in fishery problems and in fundamental work on the environment of marine organisms.

The laboratory is open throughout the year and its work is carried out by a fully qualified research staff under the supervision of the Director. The permanent scientific research staff is seventeen, and during the course of a year about 150 visiting scientists work in the laboratory for periods varying from a fortnight to twelve months. The laboratories are now equipped for a very wide range of work and the researches of the staff cover the field of chemistry and physics of sea water, and the many aspects of the biology of marine plants and animals, including their physiology. Accommodation is available for British and foreign scientific workers who wish to carry out independent research in marine biology, physiology and other branches of science, and visitors find facilities for most types of research for which marine organisms are needed. Arrangements are made for courses for advanced students to be held at Easter and marine animals and plants are supplied to educational institutions. Work at sea is undertaken by two research vessels and by a motor boat, and these also collect the specimens required in the laboratory. The larger of the two vessels, R.V. '*SARSIA*', is fully equipped for research at sea and carries out hydrographical, biological or geological cruises in the English Channel and its western approaches, and in deep water over the continental slope and into the Bay

of Biscay. The smaller vessel, R.V. '*SULA*', works daily within a radius of about twenty miles off Plymouth supplying the day-to-day requirements of the laboratory, while the motor boat '*GAMMARUS*' is engaged in collecting in Plymouth Sound and in the estuaries.

The library, which contains the best collection of books and periodicals on marine science in this country, houses some 25,000 volumes. Apart from the marine biological literature a wide range of scientific periodicals is taken by the library to supply the needs of the many and varied research workers in the laboratory.

Attached to the laboratory is a public aquarium which contains a fine collection of living representatives of most of the fish fauna of the coasts of Devon and Cornwall.

For the publication of the results of researches carried out at the Plymouth laboratory the Association has its own Journal, three numbers of which are produced each year. The average size of an annual volume is 800 pages.

Apart from grants and subscriptions the Association derives a certain income from the sale of specimens for teaching purposes, collecting nets and from the aquarium entrance fees. The total maintenance expenditure during 1957-58 was about £100,000.

1. The Plymouth laboratory. The aquarium is on the ground floor of the main building. On the left at the back is the library, followed by the physiology laboratory.

2. Part of the library of the Marine Biological Association's Laboratory at Plymouth showing the main catalogue.

NOTES

COCONUT SHELL AS A 'HOUSE' OF HERMIT CRABS IN SUHELI PAR, LACCADIVES

It is a lifelong job for hermit crabs to hunt for new 'houses', for at intervals they must find successively larger shells to accommodate their growing body. There has been some doubt whether or not these 'hermits' have the grace to wait until a gastropod is dead before making off with its shell. But recent observations seem to favour the view that they do not kill the snails thereby obtaining in one stroke a meal and a new home. Whatever be the means, the end remains a problem particularly to those species which grow to large sizes.

One of the unforgettable sights of Suheli Par (10°02′ N : 72°14′ E) is the hordes of hermit crabs especially *Coenobita* sp., which can be seen staggering about all over the island. These gregarious hermit crabs live mostly on shore among the stilted

roots of trees and inside the large holes and crevices at the bottom of tree trunks, etc. While the smaller ones are found inhabiting a wide variety of gastropod shells, the larger ones are often seen housed in coconut shells as shown in the photograph. Alcock (1902) reported of having seen at Minicoy one individual of *Coenobita rugosa* of such a large size that it could not find a shell big enough for a house, and so had

accommodated itself with an empty coconut. Another individual was so big that it seemed to have given up hope for finding a house, and was wandering about with its tail unprotected just like a little *Birgus latro*. The shells provide protection to the crab and when they are disturbed they quickly withdraw their body into the shell for safety, the chaelae efficiently blocking the opening of the shell. In those cases where coconut shells are used, the protection given by the house is not efficient as the animals cannot completely retreat into the shell. Further, it does not get a firm hold on the house as in the case of gastropod shells. The coconut shell protects only the soft abdomen and it is likely that the other parts do not require any such additional protection as they are very hard.

MacGinitie and MacGinitie (1949) observed that hermit crabs when hard pressed for ' houses ' will use almost anything that is hollow that can be made to serve until they find something better. As already mentioned the large Coenobitas were usually found housed in coconut shells. Examples of hermit crabs habitually using ' houses ' other than gastropod shells are known. One such case is that of the deep sea hermit crab, *Pylocheles miersii* found in the Indian Ocean which inhabits pieces of bamboo or hollow twigs of mangrove. The present one seems to be another instance in which the hermit crab habitually uses a coconut shell instead of the conventional gastropod shell for its house.

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A NOTE ON THE WHALE SHARK *RHINCODON TYPUS* SMITH, STRANDED OFF MANGALORE

On the 5th March 1959, the trainees from the Fishery Training Centre were engaged in experimental purse seine fishing about four miles off Suratkal, an active fishing centre about ten miles north of Mangalore. At mid-day, during the low tide, they sighted a shark stranded in 2-3 fathom waters. Since the trainees were on a routine fishing trip they were poorly equipped for the capture of such giant fishes ; nevertheless, the shark was fastened with a two-foot hook in the caudal fin and in its struggle it dragged the two boats a few miles out into the sea. However, by evening it became exhausted, and next morning the dead shark was towed ashore.

The colour of shark was dark grey with numerous pale spots on the head and series of similar spots alternating with pale vertical stripes on the lateral sides. Three

strong ridges were conspicuous on each dorso-lateral side. Its two jaws were studded with numerous rows of simple incurved teeth giving the characteristic rasp-like appearance.

Detailed measurements of the whale shark are as follows :

Length from the tip of the snout to the tip of the upper caudal lobe 12.1 metres.
Length from the tip of the snout to the tip of the caudal peduncle 9.84 metres.
Length of the upper caudal lobe from the caudal peduncle 2.31 metres.
Length of the lower caudal lobe from the caudal peduncle 1.55 metres.
Width of the mouth from one angle to the other 1.55 metres.
Circumference of the body in the mid-region 9.17 metres.

The shark which was a female weighed about 17 metric tons. The liver weighed 306 kgms. The stomach was gorged with greenish matter, and detailed examination of the gut contents showed remnants of algae, but as the contents were in an advanced stage of digestion, identification was not possible.

The previous records of the Whale shark on this coast are from Travancore (Pillai 1929), Karachi and Bombay (Prater, 1941), Bombay (Kulkarni 1948) and Malabar (Chacko and Mathew, 1954).

Central Marine Fisheries
Research Unit, Mangalore.

A. S. Kaikini
V. Ramamohana Rao
M. H. Dhulkhed

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A NOTE ON THE NIGHT FISHING OBSERVATIONS FROM A *KELONG*

The possibilities of night fishing with lights along the coast of Mandapam with stationary dip nets have been under experimentation for some time, and the following is a brief account of an attempt made by the author in 1956. There exists at present a lucrative fishery for 'Choodai' *Sardinella* spp. in these regions (Sekharan, 1956) where lighted torches are used from boats and the fish which are attracted to the light are scooped into nets. Similarly, use of stationary nets (Chinese dip nets) and lights is common along the backwaters of Kerala.

During January-April when waters of the Gulf of Mannar normally remain calm, an experimental *Kelong* was constructed opposite the Central Marine Fisheries Research Station, Mandapam, at about 200 metres from the shore, where the water has an average depth of 3 metres. This *Kelong*, built in the pattern of those seen in the Malaya-Indonesian Coasts, consisted of a dip net supported on a frame 3×3 metres and a platform of about 6.5 metres square around from where 4 men could raise or lower the net by means of pulleys. The lights employed were either a 300 C.P. kerosene Petromax lamp, or high and low wattage electric lamps.

The *Kelong* fishing commenced at dusk and lasted until day-break the following day. The first set of observations was made by using the Petromax lamp suspended in the centre of the net 0.75 metre above water level ; the second set was done similarly using electric lights and the power increased from 100 to 400 watts in four stages ; the third set was done with lights submerged in water with the power raised from 7 to 21 and 32 watts ; and the last set of observations was taken with a combination of the high-powered surface electric lamps and the low-powered submerged lamps—the high-powered lamps were first switched on for 30 minutes, followed by the submerged lights switched on for 5 minutes when the former were switched off and the net quickly raised for collecting the fish. The fishes were observed within a maximum radius of 15 metres when the 400 watt lamps were used ; while, they were observed around 3 metres radius within the area of the *Kelong* frame when submerged lights were in use. Even though the occurrence of the individual species varied during the four-month period when the *Kelong* was in operation, there was a noticeable dominance of species of *Gazza*, *Pellona*, *Plotosus* and *Leiognathus* and Squids in all collections. Further it was observed that the number of fish caught was more or less directly proportional to the intensity of light used. While the submerged light by itself was not effective, a combination of this with surface illumination invariably gave a much higher catch than either of the lights used singly.

It was particularly noticed that large number of fish was caught invariably one week before and one week after new-moon, commencing at about 2 hours before and ending at about 2 hours after the high tide.

Finally it may be mentioned here, that as the above observations were made from the Kelong during a short period only, more extensive work is required in order to elucidate the various aspects connected with the use of lights for night fishing.

I wish to express my gratitude to the scientific staff of the Central Marine Fisheries Research Station, who gave me all encouragement and help in the Kelong operations and in the preparation of this note.

Central Marine Fisheries
Research Station
Marine Fisheries P.O.
Mandapam Camp.

D. Edward Chellappa.

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Reference

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ON A SPECIMEN OF *SELAROIDES LEPTOLEPIS* (CUVIER AND VALENCIENNES) WITHOUT THE USUAL DETACHED ANAL SPINES

One of the characteristic features in Carangids is the presence of two spines detached from the rest of the anal fin. In the course of an investigation on the biology of *Selaroides leptolepis*, a common Carangid of this area, a specimen was collected on 11-2-1959 from Pudumadam, without the two detached spines. Except for this it resembled the normal specimens. The abnormal specimen, a female, measured 13.6 cm. in total length and weighed 28g. and had ovaries in the IV stage of maturity.

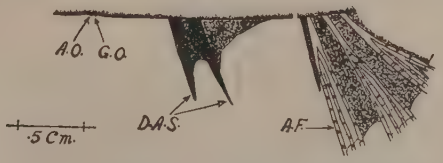

FIG. 1. Anterior portion of the anal fin in a normal specimen. D.A.S.—Detached anal spines; A.O.—Anal opening; A.F.—Anal fin; G.O.—Genital opening.

Spines appear in the juvenile stage and the youngest specimen in the collection measuring 24.5 mm. had well-differentiated spines. Accompanying sketches

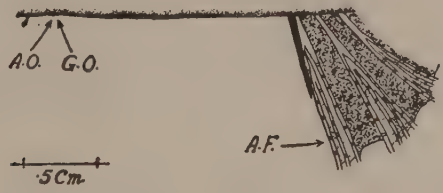

FIG. 2. Anterior portion of the anal fin in the abnormal specimen. A.O.—Anal opening; G.O.—Genital opening; A.F.—Anal fin.

show the anterior portion of the anal fin with the anal spines in a normal specimen (Fig. 1) and without the anal spines in the abnormal one (Fig. 2).

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K. K. TANDON

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NEW RECORDS OF MARINE PLANKTONIC DIATOMS FROM THE WEST COAST OF INDIA

During 1947 to 1950 the author made a taxonomic and quantitative study of the diatoms of Trivandrum coast* and recorded 121 forms belonging to 110 species, 47 genera and 12 families. Of these 114 species have been recorded previously from the Indian waters. The rest, which are new records, are :

1. *Coscinodiscus curvatulus* Grunow.
   Distr. Arctic sea, California, (Miocene deposits), West coast of North America, Nancoori deposit.

2. *Actinoptychus splendens* (Shadbolt) Ralfs.
   Distr. Wales, Atlantic and Pacific coasts of America, Colbrook Island fossil.

3. *Asteromphalus roperianus* (Greville) Ralfs var. *atlanticus* Castracane.
   Distr. Indian Ocean at 220 fathoms. Mejillones guano.

4. *Actinocyclus* sp. A hitherto undescribed species which will be described later.
   Distr. Trivandrum coast.

5. *Rhizosolenia bergonii* Peragallo.
   Distr. Atlantic Ocean, Bay of Biscay, Mediterranean, Gulf of California and Indian Ocean.

6. *Chaetoceros rostratus* Lauder.
   Distr. Open sea from the Sables d'Orlonne to Lorient, Australia, Trial Bay, France, Java Sea. A rare diatom.

7. *Campylodiscus horologium* Williams.
   Distr. Rare. Coasts of England, Scotland, Loch Fine, Coast of Skye, Japanese Sea, Red Sea, Mediterranean and Adriatic.

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Mandapam Camp.

P. V. RAMACHANDRAN NAIR.

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*This work formed part of a thesis submitted for the M.Sc. degree of the Travancore University. My grateful thanks are due to Dr. C. C. John for guidance.

AN UNUSUAL INSTANCE OF A BIRD GETTING TRAPPED BY A CLAM

On 29-8-1958 while on a field trip to Manali Island in the Gulf of Mannar a small bird similar to the common snipe was found trapped by the clam, *Catelysia opima* on a sandy stretch which was exposed being low tide then (*see* fig. below). It was about 9 a.m. in the morning and the bird was seen in a helpless condition with the tip of the beak inside the clam as shown in the photograph. Due to the weight of the clam it was unable to raise its head or stand on its legs. The valves of the clam were tightly closed and the beak which had got crushed was bleeding slightly. Except for the above, the bird was quite normal and healthy.

The clam measured 29 mm. by 35 mm. and a portion of the beak 17 mm. long was inside it. It is evident that the beak got caught inadvertently while probing the open clam lying exposed during low tide and the valves closed, too quickly for the bird to retrieve itself.

My thanks are due to Dr. N. K. Gupta, of the Punjab University College, Chandigarh, for the photograph.

Central Marine Fisheries
Research Station
Marine Fisheries P.O.
Mandapam Camp.

S. JONES.

NEWS AND COMMENTS

INTERNATIONAL OCEANOGRAPHIC CONGRESS

Conferences in Oceanography have so far been limited to some special aspect of the science or to some particular ocean area. But there has never been one in which all the marine sciences were discussed.

As a fruitful legacy of the International Geophysical Year the American Association for the Advancement of Science with the active cooperation of the International Advisory Committee on Marine Sciences of UNESCO and the Special Committee on Oceanic Research of the International Council of Scientific Unions, sponsored the International Oceanographic Congress. The meetings will be held in the United Nations Buildings in New York from August 31 to September 12, 1959.

The forenoon sessions will be devoted to lectures and the afternoon sessions to seminars. The programme is designed to cover all fields within Oceanography and have been tentatively classified under the following major subjects :

1. History of Oceans
2. Populations of the Sea
3. The deep Sea
4. Boundaries of the Sea
5. Cycles of Organic & Inorganic Substances in the Ocean.

A galaxy of international authorities on various branches of Oceanography are participating in the Congress.

Detailed information can be had from :

The American Association for the
Advancement of Science,
1515, Massachusetts Avenue,
N.W., Washington—5, D.C.

MEASUREMENTS OF PRIMARY PRODUCTION IN SEA WITH C^{14}

At a meeting of the International Council for the Exploration of the Sea held at Bergen (Norway) in September 1957 it was decided that a Central Agency be established at Charlottenlund under the direction of Prof. E. Steemann Nielsen, which would supply standardized ampoules of C^{14} and provide for the counting of the samples and calculation of the assimilation rates. With the funds provided by the UNESCO and the accommodation given by the Danish Institute for Fisheries

and Marine Research, the Central Agency commenced functioning there from January, 1958.

The Agency is organized on a non-profit basis and its facilities are available to all scientific institutions of the world. Further details can be obtained from the Central Agency.

ASSAULT ON THE INDIAN OCEAN

The Programme of the Special Committee on Oceanic Research

The International Council of Scientific Unions has planned detailed exploration of the deep seas through International Co-operation with the assistance of the UNESCO. It has appointed a Special Committee on Oceanographic Research (SCOR) with 15 members. Dr. R. Revelle (USA) is the President, Dr. G. E. R. Deacon (UK) is the Vice-President, and Dr. G. Bohnecke (Germany) is the Secretary. Dr. N. K. Panikkar of India is one of the members. Abstracts from an article in International Union of Geodesy and Geophysics Chronicle, August 1958, which gives the proposed programme of work in the Indian Ocean are given below.

'With adequate preparation during the first year it should be possible, during the third and fourth years, provided sufficient funds and ship-time become available to make a combined assault on the largest unknown area on earth, the Indian Ocean. This area is of special interest to physical oceanographers because the seasonal reversals in wind direction, unknown elsewhere provide opportunity to study the transient state in the wind-driven currents.

'It would be anticipated that in addition to scientists from the Northern Hemisphere, *scientists and students from the countries bordering on the Indian Ocean would take part in this series of simultaneous expeditions. The expedition would thus serve, not only their primary purpose of exploration, but would have a lasting effect in encouraging and developing the marine sciences and fisheries in those countries.*

'It is estimated that at least sixteen ships from eleven different countries could be enlisted. The combined scientific party on the ships would total around 125 persons; at least 25 of these might come from countries bordering the Indian Ocean area. At least one hundred scientists-years would be required for working up the results.

'During following years, when the presently severe difficulties of making measurements at depths of several thousand metres and of obtaining accurate positions on the high seas have been sufficiently overcome, a tracer experiment, using a large quantity of artificially radio-active material, should be undertaken in some suitable deep sea area.

'A programme of international cooperation in deep sea research cannot be carried out successfully without the enthusiastic support of existing international marine science organizations. Every effort will be made to utilize their facilities and procedures.

'In organizing its scientific programme, *the Special Committee on Oceanic Research will also invite the cooperation of qualified Academies or Research Councils of different countries and each participating organization will be requested to designate a corresponding member to the Special Committee.*

'The total expenditure for the proposed year-long programme of exploration of the Indian Ocean would be about $4 million, largely for ship costs. Half of this amount would come from the normal operating funds for ships and marine research laboratories of the participating countries, but additional sums totalling approximately $2,000,000 must be raised.'

WASTE DISPOSAL IN THE MARINE ENVIRONMENT

(*First International Conference, University of California, Berkeley*)
July 22-25, 1959.

Organized by the University of California Sanitary Research Laboratory, the Institute of Marine Resources and the California State Water Pollution Board and in co-operation with WHO and a number of other institutes, the conference will bring together scientists and engineers in the field of waste disposal in order to encourage an exchange of knowledge and experience on an international basis and to stimulate research in the subject area.

The programme will cover a wide range of subjects such as : Public Health, Effects on Marine Biota, Near-shore Oceanography, Estuarine Hydrography, Water Analyses and Design Considerations.

THE INTERNATIONAL ATOMIC ENERGY AGENCY

Scientific Conference on the Disposal of Radioactive Wastes
(Monaco, November 16-21, 1959)

The first international conference co-sponsored by IAEA, UNESCO, and FAO and dealing with the problems of disposal of wastes resulting from the peaceful uses of atomic energy will offer a forum for discussion amongst geologists, oceanographers and fisheries experts along with specialists from the Atomic Energy Agency and familiarize them with existing conditions and help to evolve future course of action.

Further details can be had from the
International Atomic Energy Agency,
Vienna-I, Kaerntnerring,
Austria.

THE SNORKEL LEAGUE

The Marine Biological Association had its varied activities since its formation early this year. The noteworthy feature is the formation of the Snorkel League under the auspices of the Association.

Diving, for pleasure or profit has attracted the attention of many in western countries, particularly America and Italy. People in all walks of life enjoy a swim in the cool waters of the sea watching the fantastic beauty of the life under the waves. In India, while one watches with thrill the little boys dive into the water to collect the offerings made by pilgrims at holy places like Rameswaram. or the pleasure swimmers at the seashore or the orthodox pearl divers going deep for the oysters, little interest is shown by the many in underwater sport.

Underwater sport while a recreation by itself is equally informative and a fascinating study for the naturalist. With the advent of the aqualung, underwater camera, speargun, mask etc., more and more information is obtained on the varied life pulsations of the depths.

The members of the Marine Biological Association felt that Mandapam area with its shallow waters of the Gulf of Mannar and Palk Bay, is an ideal spot to organize underwater observation as a scientific study and a pleasing diversion from the norm. This expression of the members resulted in the formation of the Snorkel League.

In the shallow waters of this area, studded with coral beds, in fact the only place along the Indian coastline with vast coral beds, much of the living beauty below the surface could be seen using goggles or diving equipments. One need not necessarily have very costly equipments like the aqualung or the closed-circuit unit to study the life in these shallow waters. Just with a pair of fins for easy propulsion in water and a good mask and snorkel it is possible to lie motionless and watch while the fishes swim by, against a background of expanded sea anemones and brilliant sponges which live fixed to the surrounding rocks covered with exquisite patterns of plants.

It is in the coral reefs that one meets with the best of underwater panorama—the brilliantly colored fish with spots, zig-zags, bands, hues of blue, pink, purple, silvery white, velvetty black ; with the blue of the sky and the green of the waters playing brilliant colours on their scales. A few minutes watching these fishes would certainly prove that it is a long way from this beautiful form to the one we see caught in the nets or sold in the market, for, the marine animals are so delicate in their cosmetic attire that unlike the land forms, they lose all the colour the moment they are caught and killed.

The few field collection trips to the Gulf of Mannar and Palk Bay, since the formation of the league, have already captured the minds of the leaguers. Especially on the coral beds of the Gulf of Mannar, we could recollect the free swimming

medusae, the fixed polyps, the sea anemones which are more delicate than the best prized Dahlias, the iridescent worms whose beauty gave them the names from mythology—Nereis, Hermione, Ophelia etc., the star fishes, brittles stars, sea urchins, sea cucumbers, the feather stars, the sponges, the brilliantly colored corals, the dancing scorpion fish, the frightened lobsters inside the crevices of rocks, and fascinating forms of green, brown and red algae. Even at this early stage, we have felt that this sport is a must for any naturalist, particularly for those who are fortunate to live near about the seaside.

The Snorkel League has made a good start, but we should admit that masks, fins and snorkels are not at present available in Indian markets, with the result, it is becoming more and more difficult for the members of the league to own their own sets of equipments. The League is at present having a few sets donated by Dr. Salvadori, F.A.O. Underwater Expert who was in India early this year and by Mr. Rodney Jonklaas of Ceylon who visited our league and who went out with us on our trips to the reefs in Palk Bay. Mr. Jonklaas has agreed to be Hon. Adviser to the League. Shri K. M. Gopal was elected as Convener. We hope, that this short note about the league, through the columns of this Journal will encourage members elsewhere in India to organise similar leagues and cultivate an interest in the life under water. We would most welcome photographs and articles on underwater studies from the members of the Association.

Explanation of Plate

Fig. 1. F. A. O. Underwater expert Dr. F. B. Salvadori (centre) with two of the Leaguers.
Fig. 2. Mr. Rodney Jonklaas, Hon. Adviser to the League.
Fig. 3. Mr. Rodney Jonklaas, at underwater photography.

(*Photographs 2 and 3 by courtesy of M/s. Wilson & Clarke Associates.*)

THE LEAGUERS IN PALK BAY

On their way to the reef.

On the reef.

Back to the shore.

MARINE BIOLOGICAL SERVICE

With a view to offering requisite information to research workers and students undergoing training in marine biological sciences, the Marine Biological Association of India has instituted a SERVICE section. Apart from giving assistance to institutions and colleges in conducting tours to places of marine biological interest, the Marine Biological Service will be issuing a series of periodical circulars dealing with the flora and fauna of the Pamban group of Islands which could be used as field guides by visiting parties.

Circular No. 1, *Issued in February* 1959.

The Pamban group of islands, Shingle, Krusadai, Pullivasal, Pulli, Manali, and Hare in the Gulf of Mannar, and Palk Bay from Devil's Point to Tondi enjoy an all-India reputation among biologists. Of these Krusadai and Shingle Islands are well known as the biologists' Paradise. But, of recent years, searches on the marine life have shown that the entire chain of islands mentioned above, is excellent ground for both the critical researcher as well as the student of biology.

Although these places are ideal grounds for field studies, their remoteness has made it rather difficult for scientists of the various educational institutions in India to visit these places frequently and conduct field studies. Excepting the Krusadai Island, where the Madras Fisheries have established a biological research station, and the Hare Island, all the other Islands in the Gulf of Mannar are uninhabited. Parties visiting these Islands generally stay on the main land at Mandapam, Pamban or Rameswaram and make daily trips to the Islands by country crafts got on hire.

Usually educational tour parties halt at Mandapam in the Marakkayar bungalow or at Pamban in the Rest House or at Rameswaram in the Choultry. Very few parties stay at the Krusadai Island. Of late, some of the visiting parties have been availing of the facilities at the Central Marine Fisheries Research Station Campus at Mandapam Camp.

The following brief note gives a general idea of the places of biological interest.

1. The Islands of Shingle, Krusadai, Pullivasal, Pulli, Manali and Hare (*See* Map p. 104). with luxuriant fringes of coral reefs, are ideal collection grounds for both marine fauna and flora. Due to constant visits by educational institutions, the flora and fauna around Krusadai are getting fast depleted and there is much restriction in large scale collection of biological specimens from this island. But all the other Islands are still virgin fields for intensive study and collection.

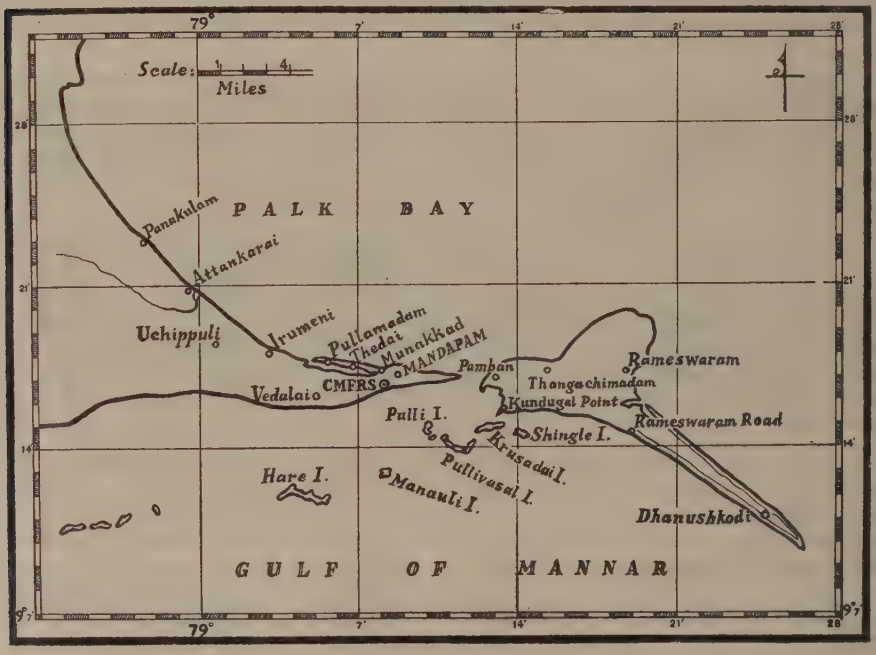
2. The Kundugal gut, with its sandy-clay and muddy banks, harbours many interesting forms of burrowing and sand dwelling forms of life.

3. The Palk Bay is, in fact not exploited by marine biologists, and it indeed, abounds in a luxuriant vegetation of animals and plants easily accessible to the students during clam periods.

4. Equally interesting is the lagoon around Tondi. Tondi is situated about 30 miles from Ramnad and is accessible by bus. There is a convenient Rest House where student parties could halt.

5. Rameswaram, apart from the famous temple, is also a very valuable seashore for biological studies of marine life. There are a number of shops where corals, shells and ' Marine curios ' are available.

6. Mandapam Camp : The Central Marine Fisheries Research Station, located about two miles from Mandapam Camp Railway Station, is another important place for both educational parties and research workers. Studies in various



Map of Mandapam area

branches of marine life are conducted there and visiting parties can get an overall picture of the different branches of fishery researches conducted in India. In addition, the library attached to the Research Station, has a good collection of books and periodicals particularly on marine biological subjects.

The best season to visit the Islands of the Gulf of Mannar is between the months of October and March, while Palk Bay including Tondi could be visited

from April to August. There is a short spell of Monsoon from the end of October to early January ; but even during this period, the rain is generally not heavy or continuous.

It has been the experience in the past years that many educational tour parties visit these places with no prior arrangements and the majority of them return much disappointed without being able to do intensive field work. This is particularly so in the case of large parties, since proper food and accommodation are very difficult without advance notice to local people.

Stay and collection at Krusadai Island could be arranged with the Director of Fisheries, Madras ; while, permission is generally given at the Central Marine Fisheries Research Station Campus by the Chief Research Officer only for short stay and for limited number of members.

PROCEEDINGS OF THE INAUGURAL MEETING OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

The Marine Biological Association of India was inaugurated by the Honourable Mrs. Lourdhammal Simon, Minister for Local Administration and Fisheries, Madras State, in the presence of a large and distinguished gathering. The function started with an invocation song by Miss H. Kamala. The President of the Association, Dr. S. Jones, welcomed the Honourable Minister and the others who had assembled. While welcoming the President spoke :

Hon. Minister, Ladies and Gentlemen,

It gives me great pleasure to welcome you all to this inaugural meeting of the Marine Biological Association of India. We are singularly fortunate in having the Hon. Minister who is in charge of Fisheries to inaugurate this infant Association which is the first of its kind to be organized in this country. It is seldom that this place gets such a galaxy of distinguished visitors. We are most happy to have with us now all the officers and technical personnel of the Madras Fisheries Department and members of the Madras State Fishery Advisory Board.

It may not be out of place to briefly refer on this occasion to the hoary traditions attached to this area from time immemorial. It was presumably over the Gulf of Mannar that Ravana piloted his aerial vehicle or ' Viman ' to kidnap the Consort of Sri Rama and it was in the sea around here that Sri Rama laid a bridge to cross over to Lanka and free Sita. Again, there are numerous other references to this area occurring in the Puranas and Vedas. The ' net casting epic' or the ' Valai Veesu Puranam ' had its origin not far from here. According to it Lord Shiva came in the guise of a fisherman and by his fishing exploits recovered his Consort Parvati who was being brought up as the daughter of a fisherman chieftain. It is possible that the Conches referred to in the Mahabarata and which were used by the mighty warriors at the great battle of Kurukshetra had their origin in the sea around this place.

Further, the seas around abound in valuable pearl oysters and the sacred chank and a rich variety of fauna and flora. The pearls from this area found their way even in far off days to Babylon, Egypt, Greece, Rome and China to cater to the vanity of the opulent. Kautilya in his *Artha-Sastra* refers to the trade in shells, pearls, etc. between the South and North and gives the place of honour among pearls to *Tamraparnika* and *Pandyakavataka*, both from these coasts. There are numerous references to pearls originating from here in ' Periplus ' and in the accounts of Pliny, Ptolemy, Megasthanes, Arrian and others and in the Tamil poems of the Sangham Age and in subsequent literature. The pearl and chank fisheries of more recent times and the struggle by various powers for monopoly over these are historically recorded and need no recounting.

This part of India has also been a meeting ground for ages between the North and the South in that pilgrims from all over the country visit Rameswaram and

other holy places and take back with them various shells and corals as sacred relics or souvenirs. Further, because of its rich marine life, this area is a paradise for marine biologists and continues to attract scientists from various parts of India to come and make biological collections. Numerous student parties from universities and colleges visit the area all the year round for educational and scientific purposes. Krusadai Island with its well-known Marine Biological Station and rich specimen collecting centres, is not far from here. More recently, the Union Government has taken steps to establish the Central Marine Fisheries Research Station with Mandapam as headquarters and investigations on various aspects of marine fish and fisheries are in progress here.

I take this opportunity to refer and pay my tribute to the great pioneering work carried out in the field of Marine Biology and Marine Fisheries by the Madras Government Museum and the Madras Fisheries Department. Very valuable work has been carried out as a result of these pioneer research investigations and marine biologists all over the country owe a deep sense of gratitude to Madras for the initiative taken in this regard. In view of the above it is only appropriate that an Association like this should be inaugurated by the Minister in charge of Fisheries of this State.

We have been for some time considering the question of organizing an Association to serve as a common platform for persons interested in Marine Sciences in India to met together with a view to promoting the cause of marine sciences, in the country. Though we have been feeling the necessity for such an Association for long time, formal discussions were initiated only very recently—just a month back to be exact—and a Constitution for the Association adopted on the 30th of last month. We have had the most promising response from scientific workers interested in marine sciences all over the country for becoming members of the Association.

Marine Biology is an infant science in this country. India has a long coastline and our marine resources remain inadequately explored and under-exploited. The object of the Association is to create a dynamic interest in the pursuit of marine sciences and raise the status, of this country in the study of this discipline. The Association is looking forward with courage and hope towards the achievement of this goal and as I referred to earlier, it is a very good augury that we have been fortunate to get the Minister in charge of Fisheries, Madras, in our midst to inaugurate the Association, and such vast assemblage of distinguished visitors. We are indeed grateful to the Hon. Minister for kindly agreeing to our request in spite of various preoccupations. I now request the Hon. Minister to formally inaugurate the Marine Biological Association of India.

The Honourable Minister inaugurated the Association with the following speech :

Ladies and Gentlemen,

At the outset, I express my profound thanks to Dr. Jones for having conferred upon me this great honour of inaugurating the Marine Biological Association of India. I understand that this is the first Association of its kind in Asia and Africa, though similar associations exist in Europe and America. And I am happy that

the association originates in Madras State. I also feel happy to know that marine biological researches were first initiated by the Madras Fisheries Department which started the Marine Aquarium at Madras in 1909. But, by establishing a marine biological station in Krusadai Island, which is only seven miles from here the Department gave considerable impetus to marine biological studies. Krusadai Island with its coral reefs is considered to be one of the richest grounds of marine animals and plants in the Indian Ocean region. It is now visited by students and professors from all over India and even from abroad for field observations on marine biota. Through the Marine Biological Station at Ennore, near Madras, the Department is supplying all varieties of marine biological specimens to several schools, colleges and universities in the country with a view to promote study of marine biology. The Department also maintains marine biological stations at Tuticorin and Cape Comorin.

Among the Universities in India, it is the Madras University that initiated researches in marine biology in the year 1927. The marine biological laboratory of this University has produced several marine biologists including Dr. Panikkar, the Fisheries Development Adviser to the Government of India, Dr. S. Jones, the President of this Marine Biological Association that I am inaugurating this evening and also many members of the Central Fisheries Station and of the Fisheries Department.

The Central Marine Fisheries Research Station at Mandapam Camp, the Chief Research Officer of which is Dr. Jones, is said to be the best marine fisheries research station in the Indo-Pacific region, with its survey, biological, hydrographical, physiological, phytological, technological, off-shore fishing and extension divisions and with its sub-stations and field units scattered along the coastline. This station is doing tremendous work for the development of the marine fisheries resources of the country. It is only appropriate therefore that the Marine Biological Association of India is started with its Headquarters at Mandapam Camp where the Central Marine Fisheries Research Station also has its Headquarters. I am confident that this Association will promote and co-ordinate both fundamental and applied marine biological studies and researches in the country.

I now inaugurate the Marine Biological Association of India, and give it my blessings and best wishes.—Thank you all.

The Secretary of the Association, Dr. R. Raghu Prasad then thanked the Minister for inaugurating the Association and the others present for readily responding to the invitation and making the function a success. The function came to a close with the National Anthem.

Inaugural address by Hon. Minister Mrs. Lourdhammal Simon, Minister for Local Administration and Fisheries. To her right is Mr. P. P. I. Vaidyanathan, I.C.S., Secretary, Govt. of Madras.

Welcome by Dr. S. Jones, President of the Association. To his left are Mr. N. Murugesa Mudaliar, Deputy Secretary, Government of Madras and Mr. C. P. Kelu Erady, I.A.S., Director of Fisheries, Madras.

Vote of thanks by Dr. R. Raghu Prasad, Secretary of the Association.

Photograph taken on the occasion of the 'At Home' by the members of the Association at Mandapam Camp on 27-5-1959 to PADMA BHUSHAN PROF. M. S. THACKER, Director-General, Council of Scientific and Industrial Research and Secretary to the Government of India, Ministry of Scientific Research and Cultural Affairs, New Delhi.

Sitting (Left to Right) : Mr. L. R. Kasturirangan, Dr. (Mrs.) F. Thivy, Mr. S. K. Banerji, Dr. S. Jones, Prof. M. S. Thacker, Dr. R. Raghu Prasad, Mr. R. Velappan Nair, Dr. R. Prasanna Varma and Dr. Samuel V. Job.

Standing—1st row : Mr. P. K. Talwar, Dr. M. D. K. Kuthalingam, Mr. V. Sadasivan, Mr. Edward Chellappa, Mr. G. Luther, Mr. K. K. Tandon, Dr. T. A. Mammen, Mr. D. Sudarasana Reddy, Mr. Egbert Dawson, Mr. M. Kumaran, Mr. T. Joseph, Mr. M. S. Rajagopalan and Mr. K. M. Gopal.

Standing—2nd row : Mr. P. R. Sadasivan Tampi, Mr. A. N. P. Ummer Kutty, Mr. P. Sam Bennet, Mr. P. S. B. R. James, Mr. M. Subramaniam, Mr. Alexander Varkey, Mr. C. Sankaran Kutty, and Mr. P. Sulochanan.

MARINE BIOLOGICAL ASSOCIATION OF INDIA

CONSTITUTION

Name of the Association :

ARTICLE 1.—The Association shall be called the ' Marine Biological Association of India '.

Purpose and Activities :

ARTICLE 2.—The object of the Association shall be to create among its members an active interest in the field of Marine Biological and allied Marine Sciences (a) by organising lectures, symposia and seminars on specific subjects, (b) by offering requisite information to research workers and students undergoing training in Marine Biological Sciences, (c) by publishing a journal, which shall be called the ' *Journal of the Marine Biological Association of India* ', (d) by issuing occasional Memoirs and Monographs, (e) by instituting fellowships and studentships to research workers at the various recognised institutions, (f) by sponsoring and aiding expeditions and (g) by instituting prizes to be awarded in recognition of outstanding contributions towards the advancement of the Marine Biological Sciences from the research workers of India, as funds permit.

The Executive Council shall decide from time to time any other means of promoting the cause of the Marine Biological and cognate Sciences in India.

Membership and privileges :

ARTICLE 3.—Membership of the Association shall be open to all persons interested in Marine Sciences.

ARTICLE 4.—The membership of the Association shall consist of the following categories :

(*a*) *Patrons*—The Patrons shall be distinguished persons holding the rank and status of Governors of States or Ministers of the Union or the State Governments or Vice-Chancellors of Universities.

(*b*) *Benefactors*—A Benefactor shall be a person/institution subscribing a sum of Rupees three thousand or more.

(*c*) *Donors*—A Donor shall be a person/institution subscribing a sum of Rupees five hundred or more.

(*d*) *Honorary Members*—Honorary Members shall be persons of eminence by their contribution to Marine Biological and allied Marine Sciences. There shall not be at any time more than fifteen Honorary Members and not more than one shall be elected each year except during the first year when not more than seven shall be elected.

(*e*) *Corresponding Members*—Corresponding Members shall be eminent Scientists residing outside India who are likely to promote the aims and objectives of the Association. There shall not be at any time more than 20 Corresponding Members. In the first year not more than ten such Members shall be elected and in subsequent years not more than two shall be elected annually.

(*f*) *Ordinary Members*—Persons or Institutions interested in Marine Biological Sciences are eligible for ordinary Membership. Persons who apply for membership during the first year are automatically admitted as Foundation Members whereas applications of all persons for membership thereafter shall be recommended by two members in good standing.

ARTICLE 5.—The annual subscription for Ordinary Members residing in India shall be Rs. 10 (Rupees ten) and in case of Members residing outside India it shall be $2.50 (Two and half U.S. Dollars) or Sh. 17.6d (Seventeen and half Shillings), payable in one instalment. Institutional membership subscription shall be Rs. 15 (Rupees fifteen) in India and $4.00 or Sh. 30 outside India. The Entrance Fee for ordinary members joining the Association in the first year of its inception shall be Rs. 2 (Rupees two) for those residing in India and $0.50 (Half a U.S. Dollar) or Sh. 3.6d (Three and half Shillings) for those residing outside India. The Entrance Fee for membership in the subsequent years to the year of inception of the Association shall be Rs. 5 (Rupees five) for those residing in India and $1.00 (One U.S. Dollar) or Sh. 7.6d (Seven and half Shillings) for those residing outside India.

ARTICLE 6*a*.—Ordinary Members may become *Life-Members* on payment of Rs. 150 (Rupees One Hundred and Fifty) in one or more instalments within a year from the date of their application for life-membership.

b.—When an Ordinary Member of some years standing in the Association desires to become a Life-Member, a rebate at a rate of one half of the annual subscription thus far paid will be allowed up to a maximum of six years.

ARTICLE 7(*a*).—Ordinary Members and Life-Members may become the Benefactors or Donors by paying the difference in subscription between the two types of membership.

(*b*).—When an Ordinary Member of some years standing desires to become a Benefactor or Donor a rebate at the same rate will be allowed as in Article 6b.

ARTICLE 8.—Patrons, Honorary Members and Corresponding Members shall be exempt from payment of entrance fee or subscriptions.

ARTICLE 9.—The Association may accept any financial contributions from persons or institutions.

ARTICLE 10.—The financial year of the Association shall be the same as the Calendar year.

The annual subscription of membership shall be paid before the end of the third month (March) of each year. A member whose subscription is in arrears shall be excluded from the privileges of the Association until the arrears are paid. If

the arrears are paid within two years after the membership has ceased no entrance fee shall be charged, but when the arrears are paid after a period of two years but not later than 5 years, one half of the entrance fee shall be collected. Full entrance fee shall be charged for the renewal of the membership after a lapse of five years.

ARTICLE 11.—When a Member relinquishes his or her Membership the Association shall not be liable to return any subscription that may have been paid before the date of withdrawal of Membership.

ARTICLE 12.—Patrons, Benefactors, Donors and all other categories of Members shall receive a copy of the Journal free of cost.

ARTICLE 13.—All Members shall be entitled to receive the publications of the Association other than the Journal at concessional rates.

ARTICLE 14.—The Headquarters of the Marine Biological Association of India shall be at Mandapam Camp.

Executive Council :

ARTICLE 15.—The Association shall be administered by a President, a Vice-President, two Secretaries, a Treasurer, an Editor of the Journal and six Members. Either the President or Vice-President and the Treasurer and one of the Secretaries shall be residents at the Headquarters of the Association. The Resident Secretary with the approval of the Executive Council shall appoint an Assistant Secretary to help him. The Assistant Resident Secretary shall hold office for three years. In the absence of the Secretary in any Meeting of the Executive Council the Assistant Resident Secretary will be co-opted and his presence shall count towards the required quorum.

ARTICLE 16.—The term of office of all Members of the Executive Council shall be three years and the Members of the said Council shall be elected by the Members present at the first General Body Meeting and thereafter by the Members present at every third annual General Body Meeting.

ARTICLE 17.—Any interim vacancies on the Executive Council shall be filled by the said Council, but the persons so appointed shall hold office till the next Annual General Body Meeting, when fresh elections shall be conducted for filling such vacancies, provided it has at least seven Members holding office. The Vice-President shall act as the President in the event of the latter relinquishing the post. In case of long and continued absence of any of the Resident office-bearers, the Executive Council shall nominate persons to act in the respective offices until the return of the regular incumbents or the next general elections whichever is earlier.

ARTICLE 18.—The Editor with the approval of the Executive Council shall constitute an Editorial Committee of himself, and two other Members, viz., a Joint Editor and a Managing Editor. The Managing Editor shall be a resident at the Headquarters of the Association. In the absence of the Editor in any meeting of the Executive Council the Managing Editor will be co-opted and his presence shall count towards the required quorum. The Editorial Committee, like the Executive Council, shall hold office for three years.

ARTICLE 19.—Notice of the Annual Meeting shall be sent to Members at least fifteen days before the Meeting and the time, place and agenda for discussion shall

be fixed by the Executive Council. Elections shall be on the basis of the majority of the Members voting and the Chairman shall exercise a casting vote when necessary.

ARTICLE 20.—Applications for the formation of Local Branches shall be considered by the Executive Council provided there are at least five members desirous of forming a branch.

General Provisions :

ARTICLE 21.—All sums of money received by way of donations and contributions from various sources and subscriptions from the Members shall be constituted into a General Fund of the Association and it shall be used for the cause of the Association either with the approval of not less than three-fourths of the Members of the Executive Council or with the approval of the majority of the Members present at the General Body Meeting.

ARTICLE 22.—The accounts of the Association shall be audited annually by a Committee of two persons appointed by the Executive Council.

ARTICLE 23.—If the Members wish to amend the Constitution, notice shall be given in writing to the Secretary with a draft on the proposed amendment under the signatures of not less than 10 Members which shall then be circulated to all Members at least one month before the next Annual General Body Meeting and thereafter it shall be placed before the said meeting for discussion. If two-thirds of the Members present at the Annual General Body Meeting vote in favour of the proposed Amendment it shall be duly given effect to.

REGULATIONS

I. The President on the recommendation of the Executive Council shall invite such distinguished persons as stated in article 4 to become the Patrons.

II. During the first year the Honorary and Corresponding Members shall be nominated by the Members of the Executive Council and each member shall propose not more than one name against each category of the Honorary Membership. The nominations shall be received by the Secretary not later than 31st January, 1959. The Honorary Members and Corresponding Members shall be elected by a majority of not less than three-fourths of the Members of the Executive Council. The number of such Honorary Members shall be within the limits stated in article 4 (d) and (e) of the Constitution.

In the subsequent years the elections of the Honorary Members and the Corresponding Members shall be conducted in the same manner as in the first year except that the nominations shall be received by the Secretary till 30th June of each year and the results of the election by the Executive Council shall be confirmed by the Members of the General Body at the next Annual Meeting.

III. The Executive Council shall incur all items of expenditure including the publication of Journal from the General Funds of the Association. On any special items of expenditure exceeding Rs. 500 the approval of the General Body shall be obtained before such expenditure is incurred. During the course of a year the Treasurer shall not incur expenditure exceeding a sum of Rs. 200 on items for which it is not possible to obtain the prior approval of the Executive Council.

THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

Terms of Membership

India :

Life membership, Rs. 150 Composition fee.
Individual membership, Rs. 10 per annum.
Entrance fee, Rs. 5
Institutional membership, Rs. 15 per annum.

Foreign :

Life membership, Rs. 200 Composition fee.
Individual membership, Rs. 12.50 per annum.
Entrance fee, Rs. 5.
Institutional membership, Rs. 20 per annum.
Subscriptions may be paid in Dollars, Pound Sterling or equivalent in any other currency.

Members of the Association have the rights and privileges to elect the Officers and Council, and they receive the Journal of the Association free.

* * * * *

JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

(Official organ of the Marine Biological Association of India)

This Journal is published half-yearly in June and December and is devoted to all branches of marine biological and cognate sciences in India and abroad.

Price for Vol. I, Rs. 35, exclusive of postage.

Free to members of the Marine Biological Association of India.

N.B.—Vol. I, No. 1, has gone out of stock and a limited number of copies are being reprinted. Numbers 1 and 2 of Volume I, will not be sold separately. Only *whole* volume will be offered for sale.

* * * * *

MARINE BIOLOGICAL SERVICE

For the convenience of the various educational institutions interested in conducting field studies on the marine fauna and flora, the Marine Biological Association of India, with its headquarters at Mandapam Camp, has organised a Marine Biological Service in an endeavour to assist *institutional members* in organizing educational tours to the places of marine biological and fishery importance. The various Educational and Research Institutions and the different Universities in India are invited to avail of the service offered by the Marine Biological Association of India.

* * * * *

For all particulars regarding the MARINE BIOLOGICAL ASSOCIATION OF INDIA and the JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, write to the Secretary, Marine Biological Association of India, *Marine Fisheries P.O.*, Mandapam Camp, S. India.

REGISTRATION OF NEWSPAPERS (CENTRAL) RULES 1958

Statement about ownership and other particulars about newspaper
(JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA)
to be published in the first issue every year after the last day of February

FORM IV

(SEE RULE 8)

1. *Place of Publication*—Chepauk, Madras 5.
2. *Periodicity of its publication*—Half-yearly.
3. *Printer's Name*—V. M. Philip.
   Nationality—Indian.
   Address—Diocesan Press, 10, Church Road, Vepery, Madras-7.
4. *Publisher's Name*—Dr. R. Subrahmanyan, for Marine Biological Association of India.
   Nationality—Indian.
   Address—Marine Fisheries P.O., Mandapam Camp, Ramnad.
5. *Editor's Name*—(1) Prof. P. N. Ganapathy, (2) Dr. R. Subrahmanyan.
   Nationality—Indian.
   Address—(1) Dept. of Zoology, Andhra University, Waltair. (2) Marine Biological Association of India, Room No. 3, Biochemical Laboratory, Chepauk, Madras-5.
6. *Names and addresses of individuals who own the newspaper and partners of shareholders holding more than one per cent of the total capital*—Scientific Journal, published by the Marine Biological Association of India.

I, R. Subrahmanyan, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Date—30-8-1960

(Sd.) R. SUBRAHMANYAN,
Signature of Publisher.

PRINTED IN INDIA, BY V. M. PHILIP,
AT THE DIOCESAN PRESS, MADRAS 7 AND PUBLISHED BY DR. R. SUBRAHMANYAN,
ON BEHALF OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, MADRAS 5
15-10-1960. C3684

INSTRUCTIONS TO AUTHORS

1. Papers offered for publication in the Journal of the Marine Biological Association of India should be typewritten on one side and double spaced on foolscap paper and should not exceed fifty pages. A slip proof will be sent to the author for correction whenever possible. The cost of excessive corrections in the proof will be charged to the authors and hence all papers should be sent in their final form for printing.

2. The title of the paper should be brief and to the point and typed wholly in capitals. This is followed by the author(s) name(s) with the initials preceding the surname. No periods follow the title or the author's name(s).

3. Tables when given should not contain bulky data and should be given on separate sheets and their position in the text indicated suitably. They should be neatly typed without any overlapping of the columns and should be given brief headings. They should be numbered in Roman numerals and indicated in the text thus : Table I.

4. Both tables and graphs illustrating the same point will not be accepted.

5. Drawings or illustrations should be made in Indian ink on white Bristol board or tracing paper and normally to twice that of the final printed size. Scale of magnification of *camera-lucida* drawings should be indicated beside the drawing itself. Photographs or photomicrographs when sent should show good contrast and be properly mounted. Every drawing or photograph should be accompanied by the relevant legends. Maps should have the latitude and longitude clearly marked. The size of the printed area of the Journal is 18 × 12 cm. and this will be maximum size for a full page figure with legend. Figures should be numbered in Arabic numerals and indicated in the text thus : Fig. 1.

6. The relative importance of the headings in the *MSS* should be shown by their position on the page and by proper use of the capitals and lower case as given below :

First order—centre heading, all capitals ;

Second order—centre heading, capitals and lower case ;

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7. Names of all simple chemical compounds rather than their formulae should be used in the text. When Greek symbols or unusual signs which normally cannot be typed are used, they should be written out quite legibly and made easy to differentiate as between : 'K' upper case and 'k' lower case. Similarly complex mathematical equations should also be clearly written out if they cannot be typed fully. All measurements should be given in the metric system only.

8. Each article should include a summary not exceeding 300 words. An abstract in the form acceptable to all abstracting journals should accompany the article. Articles in languages other than English will also be considered subject to the availability of the types and should always contain a summary in English.

9. Citation of literature should have author, year, title, name of journal, volume number and inclusive pages. Abbreviations of the names of journals should be according to '*World List of Scientific Publications*' (3rd *ed.* 1952), or to recognised forms only. Examples :

Fogg, G. E. 1952. The Production of extra cellular nitrogenous substances by a blue green alga. *Proc. roy. Soc* (*London*), **B 139** : 372-397.

Harvey, H. W. 1931. *Biological Chemistry and Physics of sea water*. Cambridge Univ. Press.

In the text the reference should be cited thus : Allen and Nelson (1930), with the author's surname followed by the year of publication in parenthesis.

10. For every contribution, the author(s) will be supplied *gratis* 10 reprints of the article without covers. The number of extra copies required with or without covers must be communicated to the Managing Editor. The extra reprints will be supplied at cost price plus postage together with the Free copies.

11. All *MSS* should be sent to :

The Managing Editor,
Marine Biological Association of India,
Marine Fisheries P.O.,
Mandapam Camp, S. India.

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